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BROCK, V. E. and R. RIFFENBURGH
Fish schooling: A possible factor in reducing predation. Proceedings Hawaiian Academy of Science, 34th Annual Meeting. Abstract p. 32-33.

CALLAWAY, R. J. and J. W. MC GARY
Northeastern Pacific albacore survey Part 2. Oceanographic and meteorological observations. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 315, 133 p.

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Effect of water clarity on albacore catches. Limnology and Oceanography 4(1): 86-93. Jan. 1959.

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5. Secular Warming in Sea Surface Temperatures, Equatorial Pacific, 1955-1958

During the months of November, 1955, through January, 1956, sea surface temperatures in the eastern and central equatorial Pacific were from 0.5 to 2.5° F. cooler than normal. Subsequently, mean monthly sea surface temperatures in these areas, although exhibiting comparatively normal seasonal variation, were increasingly warmer than normal. The upper limit of the trend was reached in January, 1958, when these temperatures in the eastern central equatorial Pacific were 4°–6° F. above normal. The trend, as measured at the Christmas Island station, then reversed and by August, 1958, the temperatures were approaching the normal. A comparable reversal was not as apparent in equatorial waters to the north and south of Christmas Island.

Daily temperatures from Christmas Island in the Line Islands group, and temperatures at frequent intervals measured by Matson vessels between Honolulu and Samoa and by POFI vessels in oceanic areas near the Marquesas Islands were the principal data used for the analyses. Consideration of similar data from the north central and northeastern Pacific indicates that the higher than normal temperatures observed in the eastern and central equatorial Pacific during 1957 and early 1958 were characteristic of a large segment of the Pacific Ocean.

Although available data are as yet inadequate to confirm the hypothesis, consideration of both the surface and the subsurface temperatures (to 900 feet below the surface) near the Christmas Island station and in the Marquesan waters suggests that the above-described higher than normal temperatures during 1957 and early 1958 resulted primarily from advection and not from localized heating.

THOMAS S. AUSTIN
Pacific Oceanic Fishery
Investigations
Honolulu, Hawaii

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Thirty-Fourth Annual Meeting • 1958-1959

1959

12. FISH SCHOOLING: A POSSIBLE FACTOR IN REDUCING PREDATION

This paper considers the possibility that fish schooling is a mechanism for protection against predation. There are two factors operating at cross-purposes: Regarding a single fish as a group of size one, schooling (a) reduces the number of groups and consequently the chance of detection, and (b) increases the size of groups, thus increasing the chance of detection. A third factor which may give an advantage to schooling is the limitation of capacity of the predator.

An expression is developed for the probabilities that a predator sights (and therefore eats) a nonschooled forage fish and a schooled forage fish. From these probabilities, an expression is found for the expected number of forage eaten when they school and when they do not school. Other things being equal, if the expected number of schooled forage eaten is less than the expected number of nonschooled forage eaten, then schooling is advantageous to the forage.

Since the number of forage a predator can eat is never more than the number present but may be less, the formulae can be simplified somewhat, leaving the advantage or disadvantage to forage through schooling as an inequality of probabilities. The probability distributions of the variates are found so that the probabilities in the inequality may be evaluated; such probabilities depend on four constants: average distance between predator and forage, standard deviation of this distance, sight range of the predator, and a size measure of a school of forage.

It is shown that for any reasonable values of these constants, the probability of detecting any particular forage fish is approximately the same whether it is schooled or not so that the meaningful consideration in the number of forage eaten when schooled vs. when not schooled is the reduced frequency of the predator's encounter with schooled forage. For example, if the predator meets 70 forage a week and can hold 10 at one feeding, he eats optimally if he finds 10 nonschooled forage a day; however, he may starve if he finds one school of 70 in the week, at which time he can hold only 10. Thus the meaningful factors in schooling advantage are (1) predator capacity, (2) the period of association of predator and school, and (3) school size. It is shown that as the number of forage fish in a school increase (total forage held constant), the consumption rate of forage by the predator will decrease.

VERNON E. BROCK
Bureau of Commercial Fisheries
Honolulu, Hawaii

ROBERT H. RIFFENBURGH
Bureau of Commercial Fisheries
and University of Hawaii
Honolulu, Hawaii

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THIRTY-FOURTH ANNUAL MEETING • 1958-1959

Northeastern Pacific Albacore Survey
Part 2. Oceanographic and Meteorological Observations

SPECIAL SCIENTIFIC REPORT---FISHERIES No. 315

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State or cooperating Agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Fred A. Seaton, Secretary

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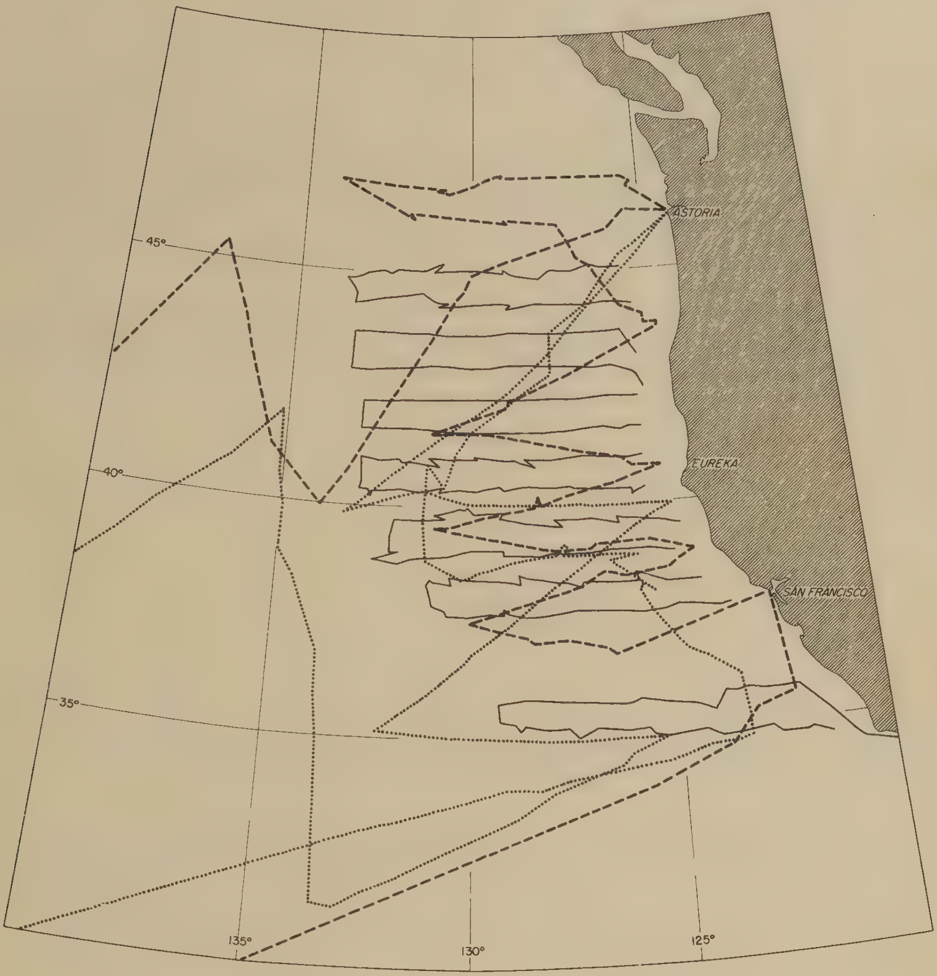
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NORTHEASTERN PACIFIC ALBACORE SURVEY

PART 2. OCEANOGRAPHIC AND METEOROLOGICAL OBSERVATIONS

By

Richard J. Callaway

and

James W. McGary, Oceanographers
Bureau of Commercial Fisheries
Biological Laboratory
Honolulu, Hawaii

Special Scientific Report--Fisheries No. 315

WASHINGTON: JULY 1959

ABSTRACT

Oceanographic and meteorological observations obtained aboard the United States Fish and Wildlife Service research vessels Hugh M. Smith and John R. Manning during Operation NEPAS in 1957 and en route to and from Hawaii are presented in this report. It also contains a summary of the limited oceanographic observations made by the eight contract vessels. Data are published without analysis or interpretation to make them available to other investigations in the north PACIFIC area.

The field and laboratory procedures are briefly described. The vertical and horizontal distribution of temperature, salinity, dissolved oxygen, and inorganic phosphate off the coasts of California Oregon, and Washington are presented in tables, station curves, and surface plots. Secchi disc, Forel color, and photometer measurements are tabulated by vessel.

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NORTHEASTERN PACIFIC ALBACORE SURVEY

PART 2. OCEANOGRAPHIC AND METEOROLOGICAL OBSERVATIONS

by

Richard J. Callaway[1]

and

James W. McGary, Oceanographers
Bureau of Commercial Fisheries
Biological Laboratory[2]
Honolulu, Hawaii

The Northeastern Pacific Albacore Survey (NEPAS) was a survey of the abundance and distribution of the albacore, Germo alalunga (Bonnaterre), conducted in a band approximately 350 miles wide off the coasts of northern California, Oregon, and Washington between 35°N. and 47°N. latitude from July 22 to August 1, 1957. Meteorological and oceanographic observations, the data from which are presented in this report, accompanied the biological sampling program. It was conducted by the Honolulu Biological Laboratory, Bureau of Commercial Fisheries as part of their Saltonstall-Kennedy albacore project in cooperation with fishery research agencies of California, Oregon, and Washington. The Pacific Marine Fisheries Commission provided liaison among the cooperating agencies.

A total of 11 vessels participated in the survey. The Fish and Wildlife Service research vessel Hugh M. Smith acted as coordinating vessel and conducted most of the detailed oceanographic observations (see fig. 1). The Fish and Wildlife Service research vessel John R. Manning made a preliminary fishing survey of the NEPAS area and did additional fishing in the areas where the contract vessels reported their better catches. The Manning also made a limited number of oceanographic observations. Her track is shown in figure 2. Nine contract vessels started the trolling survey but only seven completed their assigned tracks (see fig. 3). The other two vessels were forced to withdraw before they had contributed materially to the survey. The tracks of the seven contract vessels completing the survey are shown in the frontispiece. The owners, the observers and the agency providing the observer are listed in table 1.

This report contains the oceanographic and meteorological observations taken aboard the Smith and Manning and the surface observations made by the contract vessels. The field and laboratory procedures are also described. The biological data collected during the survey, except for the plankton, have already been reported by Graham (1959). The plankton data will be contained in a later report.

FIELD PROCEDURES

Water Sampling Program

Seventy oceanographic stations were occupied by the Hugh M. Smith at the positions shown in figure 1 and listed in table 2. From Honolulu to 38°35'N., 142°28'W. and from 33°36'N., 126°30'W. to Honolulu, Nansen bottle casts were made at 0800 and 2000 zone time (total 30). Only one cast was made each day (total 40) in the survey area since the vessel usually hove to at night, in order to make a continuous trolling survey along her track. Trolling was conducted at 6.5 knots during the day.

At each oceanographic station a cast of 13 Nansen bottles was made to approximately 1200 meters. The spacing of the bottles in the upper 300 meters was determined by the characteristics of a bathythermograph trace obtained just prior to the station. The remaining bottles were placed at standard depths. Paired protected reversing thermometers were attached to each bottle. All but the upper four bottles (those at approximately 100 meters or less) carried an unprotected reversing thermometer.

Water samples were drawn from each Nansen bottle for salinity, oxygen, and inorganic phosphate determinations. At stations 99, 139, 147, and 156 additional samples were drawn for boron analysis. These samples were shipped to Mr. James Gast of the University of Washington for analysis.

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[1] Presently employed at the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington.

[2] Formerly the Pacific Oceanic Fishery Investigations.

Surface samples for determination of salinity and inorganic phosphate were taken at most of the off-station BT casts. Surface salinity samples were taken by the Hugh M. Smith at approximately 30-mile intervals from Honolulu to the survey area, from the survey area to Honolulu, and surface salinity and inorganic phosphate samples were taken at each off-station BT cast in the survey area. Salinity and inorganic phosphate samples were taken by the John R. Manning at approximately 60-mile intervals from Honolulu to Astoria and at approximately 30-mile intervals from Astoria to 30°N. latitude (see fig. 2 for her track).

Bathythermograph Observations

A 900-ft. BT cast was made from the Hugh M. Smith, before and after each Nansen bottle cast. When surface temperatures were 66°F. or less, BT casts were made at intervals of not more than 15 miles, when abrupt surface temperature changes were indicated on the recording thermograph, and each time albacore were landed if one hour had elapsed since the previous lowering. At surface temperatures greater than 66°F. two BT's were taken between oceanographic stations. The positions of and observations made at the Smith's BT casts are given in table 3.

From the John R. Manning, 900-ft. BT casts were made at approximately 30-mile intervals and also before and after each gill-net station. From Astoria, Oregon, to about 30°N. latitude, 450-ft. BT casts were also made at 0300 zone time on the nights when the gill nets were set. The positions of and the observations made at the Manning's BT casts are given in table 4.

The BT slides were processed by the United States Navy Hydrographic Office and the data were used to construct the temperature cross sections along the vessel tracks; Hugh M. Smith in figures 4 to 16 and John R. Manning in figures 17 to 27. The portion of the tracks included in each of the cross sections is indicated by the letters on the vessel tracks (figs. 1 and 2).

Meteorological Observations

Synoptic weather observations as outlined in the United States Weather Bureau Circular M (1956) were made aboard both our vessels at 0000, 0600, 1200, and 1800 GCT and transmitted to the United States Weather Bureau at Honolulu or San Francisco, whenever radio conditions permitted. A summary of these observations as recorded on United States Weather Bureau Form 1210F are listed in tables 5 (Smith) and 6 (Manning).

Subsurface Illumination and Water Color Measurements

Measurements of the percentage of subsurface illumination relative to that at the sea surface were made from the John R. Manning at 75 stations. Measurements were made not earlier than two hours after sunrise and not later than two hours before sunset. A Schueler photometer, which has been described by Callaway (1957), was used. The response curve of the photometer matched the standard curve of the International Commission on Illumination which has a spectral range of 430 to 700 millimicrons and a peak sensitivity at 550 millimicrons[3]. The total incident light was estimated in foot candles with a standard camera exposure meter. Because the cable to the sea cell broke repeatedly, the 1-percent level of illumination was measured only occasionally. Some values at the 50-percent and 10-percent levels are also open to question because the shadow of the ship's hull and rigging interfered. The results are given in table 7.

Secchi disc and Forel water color observations were made from both the Manning and Smith. The Secchi disc observations were made in the manner described in the United States Navy Hydrographic Office Publication 607 (1955). Water color as it appeared according to Forel's scale against the Secchi disc background was also made at each lowering. Aboard the Smith these observations were made at 0800 zone time while operating outside the NEPAS area. Within the area they were made daily at 1300 zone time and after each albacore school had been worked when light and sea conditions were suitable. The Smith's results have been included in table 2. Aboard the Manning they were made simultaneously with the photometer measurements and have been included in table 7.

Observations by the Charter Vessels

Each charter vessel was provided with bucket thermometer and a Secchi disc. They made surface temperature observations to the nearest half degree every four hours while underway and after each albacore school had been worked. The observed temperatures are not included in this report but have been used in constructing the surface temperature plot, figure 28.

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[3] Weston Photronic Photoelectric Cells, Weston Electrical Instrument Corporation Circular B-27-A, February 1949.

Secchi disc and cloud cover observations were made each day at local noon. The results are listed in table 8.

LABORATORY PROCEDURES

Chemistry

Salinity samples were placed in glass bottles and sealed with paraffin-impregnated corks and screw caps. Double titrations were made in the Honolulu laboratory using a modification of the Knudsen method. This modification (Van Landingham 1957) results in a stoichiometric end point and involves the use of an adsorption indicator, phenosafranin, in the presence of starch as a protective colloid. The surface salinities at the off-station BT's are given in tables 3 (Smith) and 4 (Manning) and those for the Smith's oceanographic stations in table 9. A plot of the surface salinity is shown in figure 29.

Dissolved oxygen analyses were performed aboard the Hugh M. Smith by the Winkler method. These results are also contained in table 9.

The inorganic phosphate samples were placed in screw-cap culture tubes, sealed with plastic tape, and quick, dry-frozen for analysis ashore. Analysis was performed in the Honolulu laboratory using a modification of Denige's method developed by Van Landingham[4]. The values for the surface samples taken at the off-station BT's are included in tables 3 (Smith) and 4 (Manning) and the values for various depths at the Smith's oceanographic stations 19 through 139 are listed in table 9.

Oceanographic Processing

Processing of the oceanographic data was performed at the Honolulu laboratory under the supervision of Mrs. M. L. Godfrey.

The presentation of the data is similar to that of King et al. (1957) in that only the observed station data are listed (table 9). In order to facilitate further use of the data, graphs showing the complete set of curves are also given for each station.

In the upper 300 meters one of the BT traces taken at the station was used as a guide in constructing the temperature depth curve for the reversing thermometer readings. To insure continuity among the various parameters, salinity and oxygen are shown as curves plotted against temperature rather than depth (Montgomery 1954). Station to station continuity was maintained by utilizing the curves for adjacent stations in constructing the curves for each parameter.

Although the inorganic phosphate data are included in the tabulations, they have been omitted from the station curves. This was because values in the vicinity of the oxygen minimum seemed to vary erratically. This will require further study and comparison with data from other sources to determine whether the variations are real or may have been caused by handling of the frozen samples.

Isopleths of thermosteric anomaly are shown on each station graph in lieu of the customary isopleths of sigma-t. This was done to permit the computation of dynamic heights by the method of Montgomery and Wooster (1954). This method differs from the conventional method (LaFond 1951) in that the pressure terms of the specific volume anomaly are neglected. The surface heights (geostrophic currents) relative to the 1,000 decibar level are shown in figure 30 to indicate the general circulation through the area.

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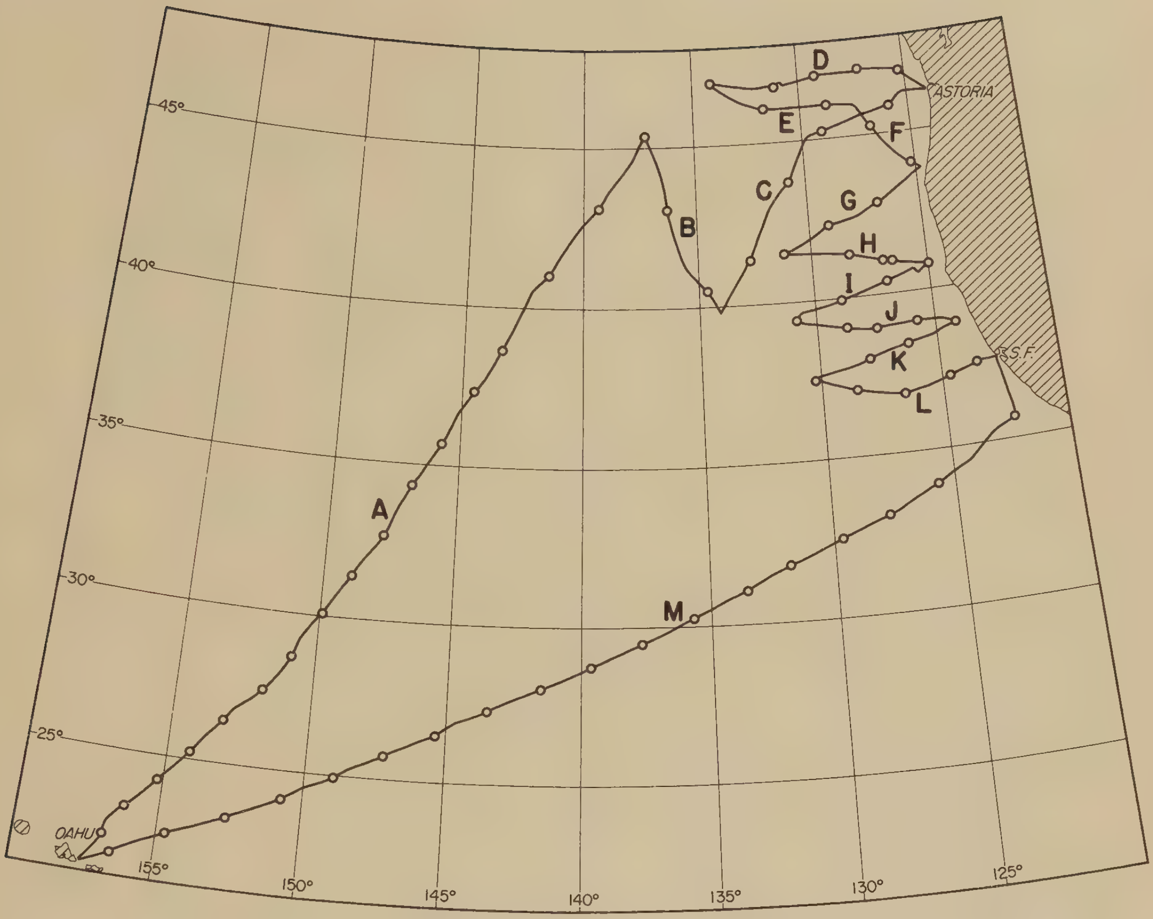
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Figure 1.--Track chart, Hugh M. Smith cruise 40 (NEPAS), July 1-September 5, 1957. Circles indicate oceanographic station positions and letters designate the location of the temperature sections shown in figures 4-16.

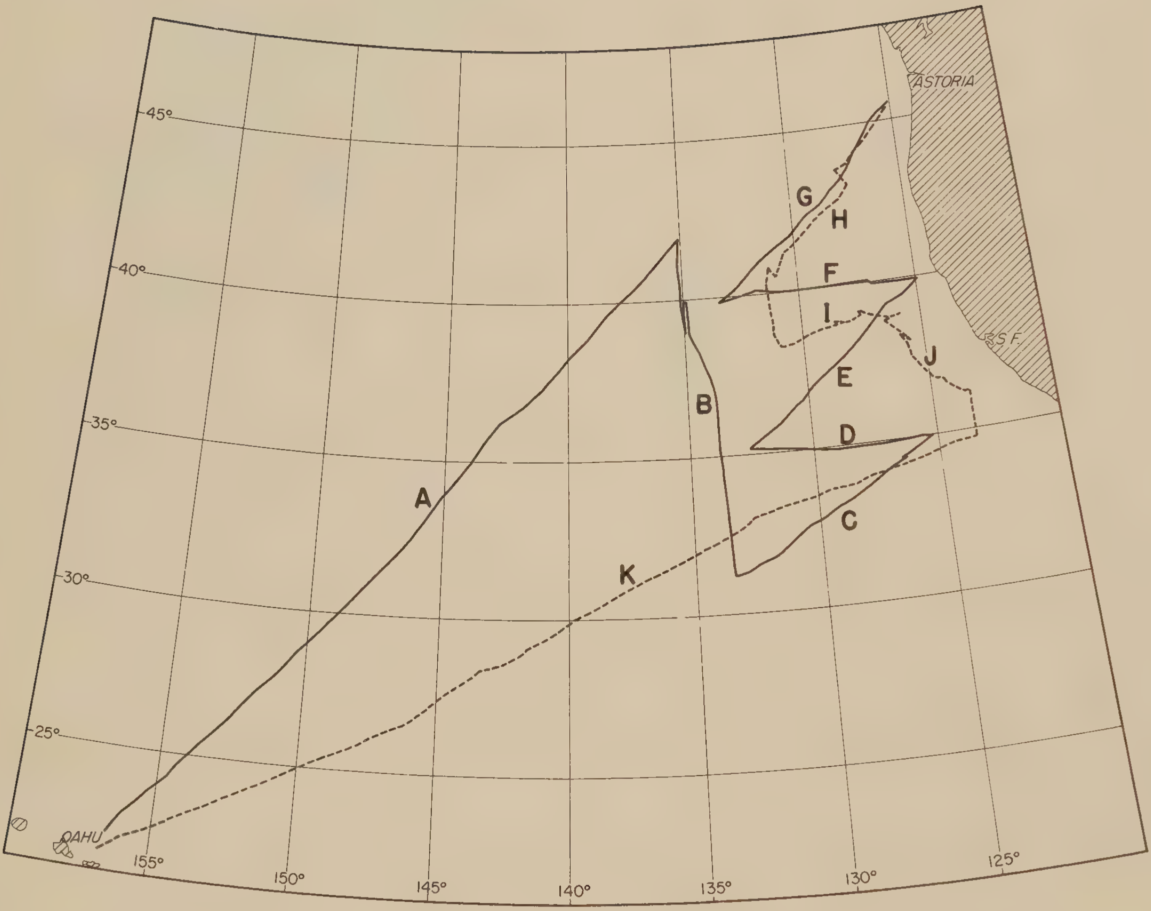
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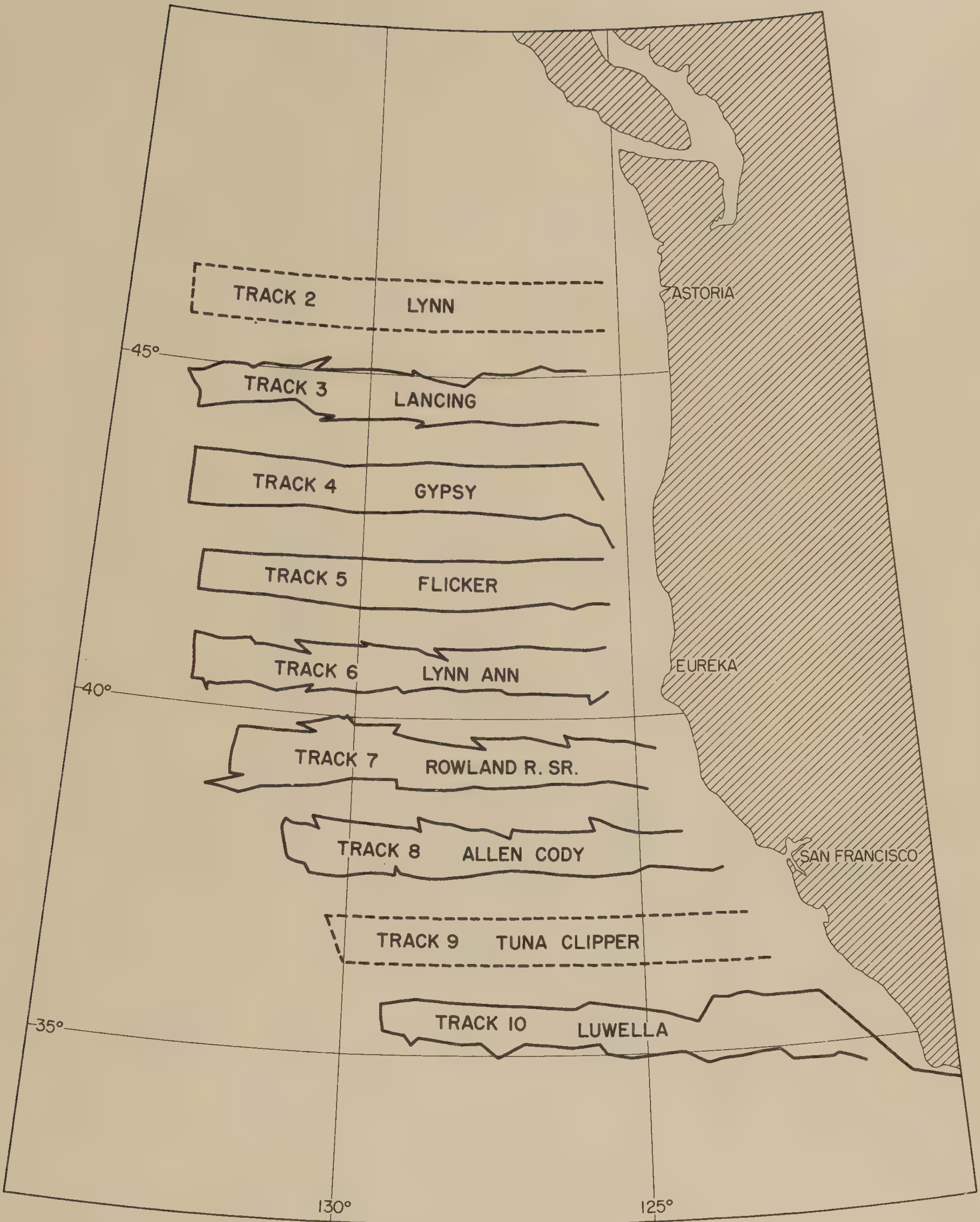
Figure 2.--Track chart, John R. Manning cruise 36 (NEPAS), June 11-August 20, 1957. Solid line - Honolulu to Astoria. Dashed line - Astoria to Honolulu. Letters designate the location of the temperature sections shown in figures 17-27.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FLICKER
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TRACK 8
ALLEN CODY
TRACK 9
TUNA CLIPPER
TRACK 10
LUWELLA
35°
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Figure 3.--Track chart, NEPAS charter vessels. July 22-August 1, 1957. Solid lines indicate actual tracks, broken lines indicate tracks assigned but not completed.

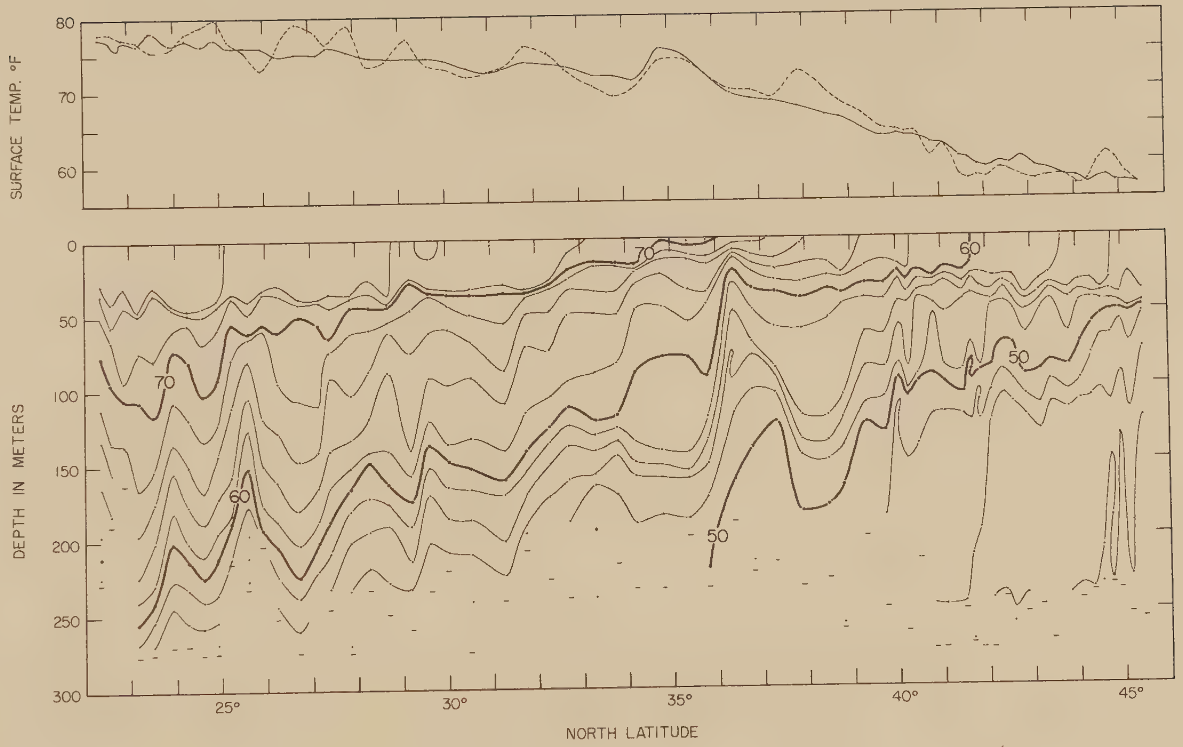
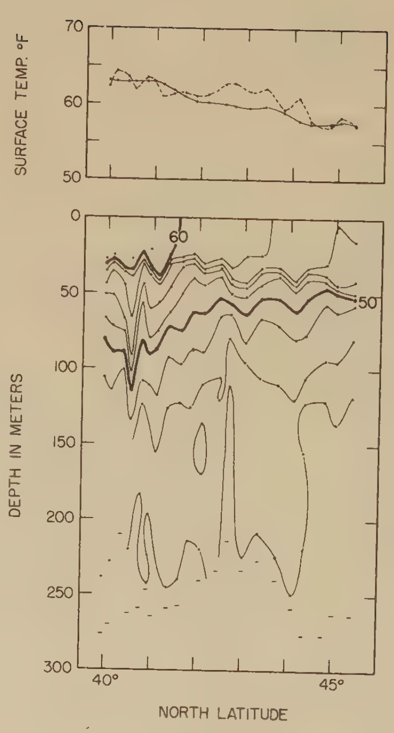
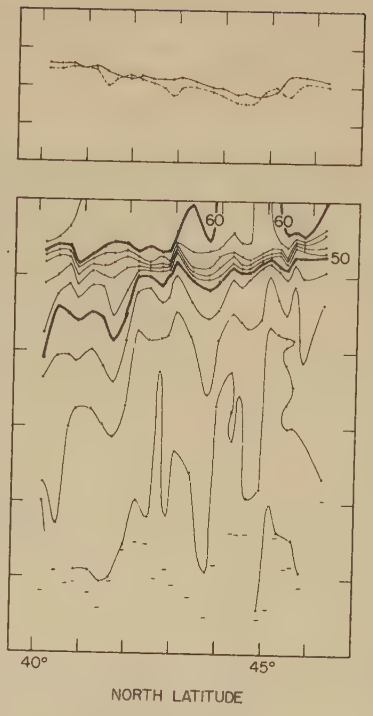
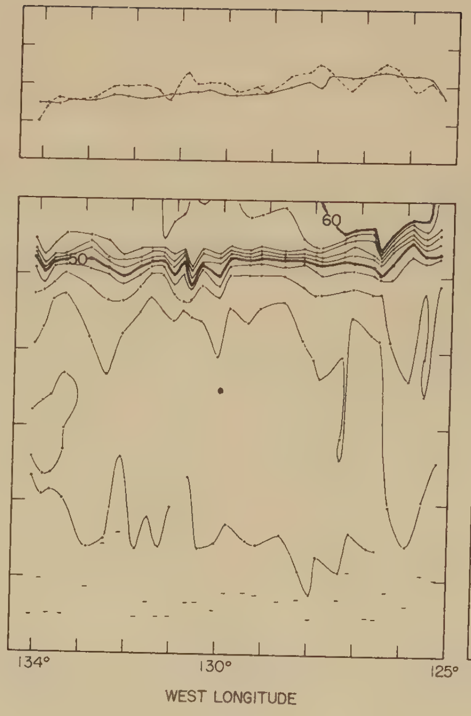


Figure 4.--Temperature sections from BT casts along Section A (see fig. 1), *Hugh M. Smith* cruise 40 (NEPAS), July 1-September 5, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.







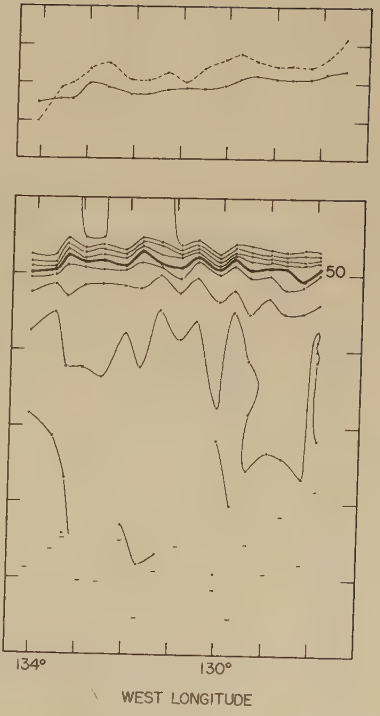
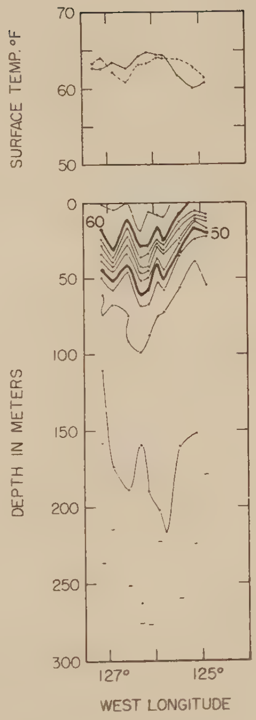


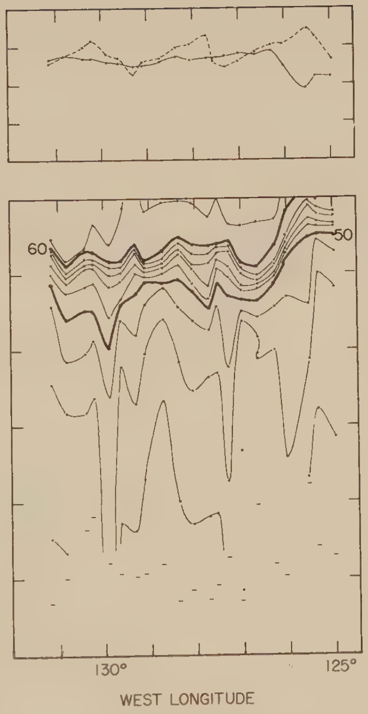
Figure 5.--Temperature sections from BT casts along Section B (see fig. 1), Hugh M. Smith cruise 40 (NEPAS), July 1-September 5, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.

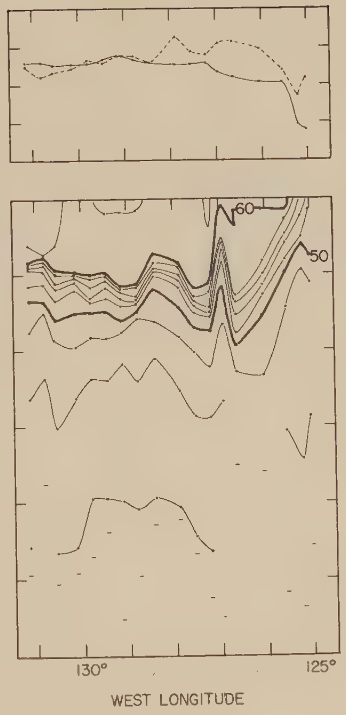
Figure 6.--Same along Section C (fig. 1).

Figure 7.--Same along Section D (fig. 1).

Figure 8.--Same along Section E (fig. 1).







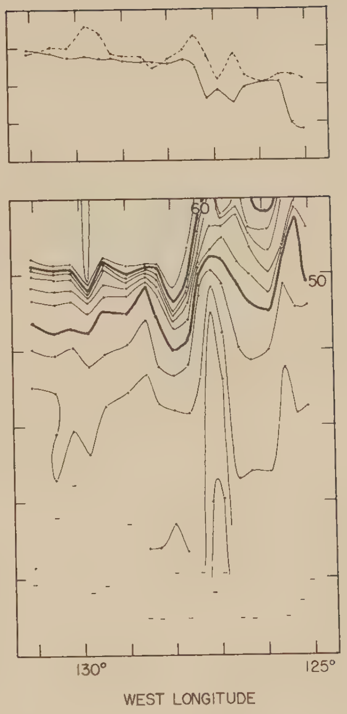
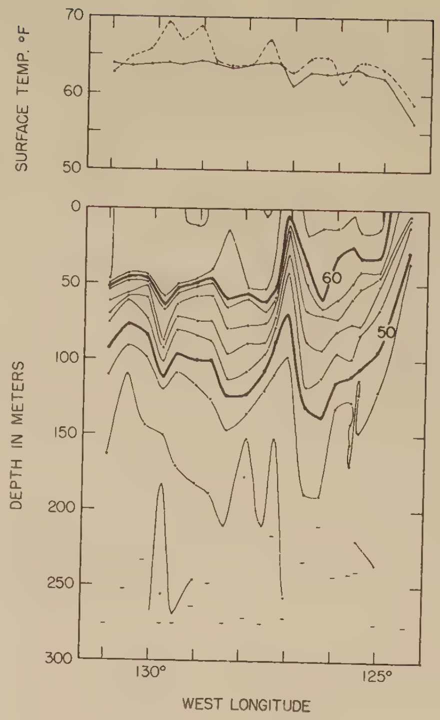


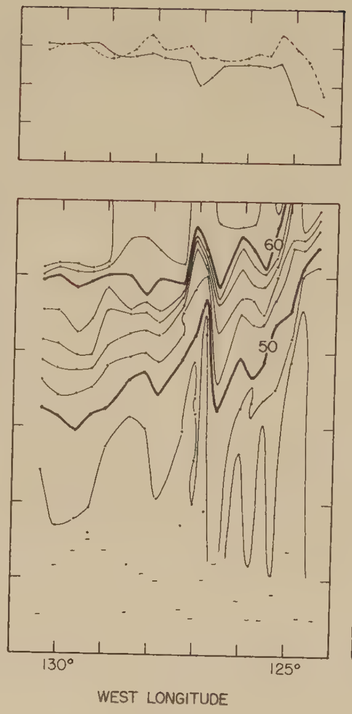
Figure 9.--Temperature sections from BT casts along Section F (see fig. 1), Hugh M. Smith cruise 40 (NEPAS), July 1-September 5, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.

Figure 10.--Same along Section G (fig. 1).

Figure 11.--Same along Section H (fig. 1).

Figure 12.--Same along Section I (fig. 1).





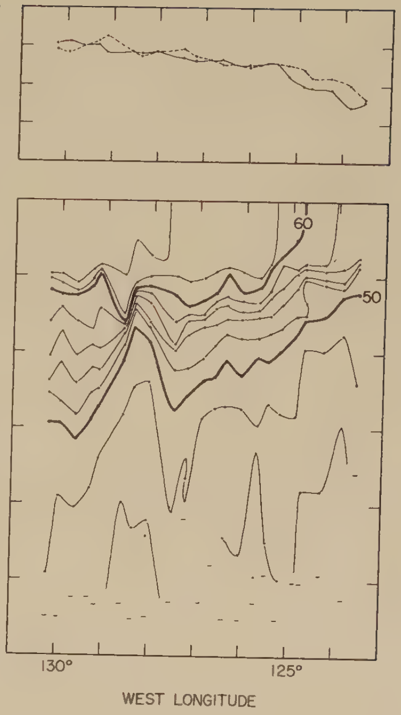


Figure 13.--Temperature sections from BT casts along Section J (see fig. 1), *Hugh M. Smith* cruise 40 (NEPAS), July 1-September 5, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.

Figure 14.--Same along Section K (fig. 1).

Figure 15.--Same along Section L (fig. 1).

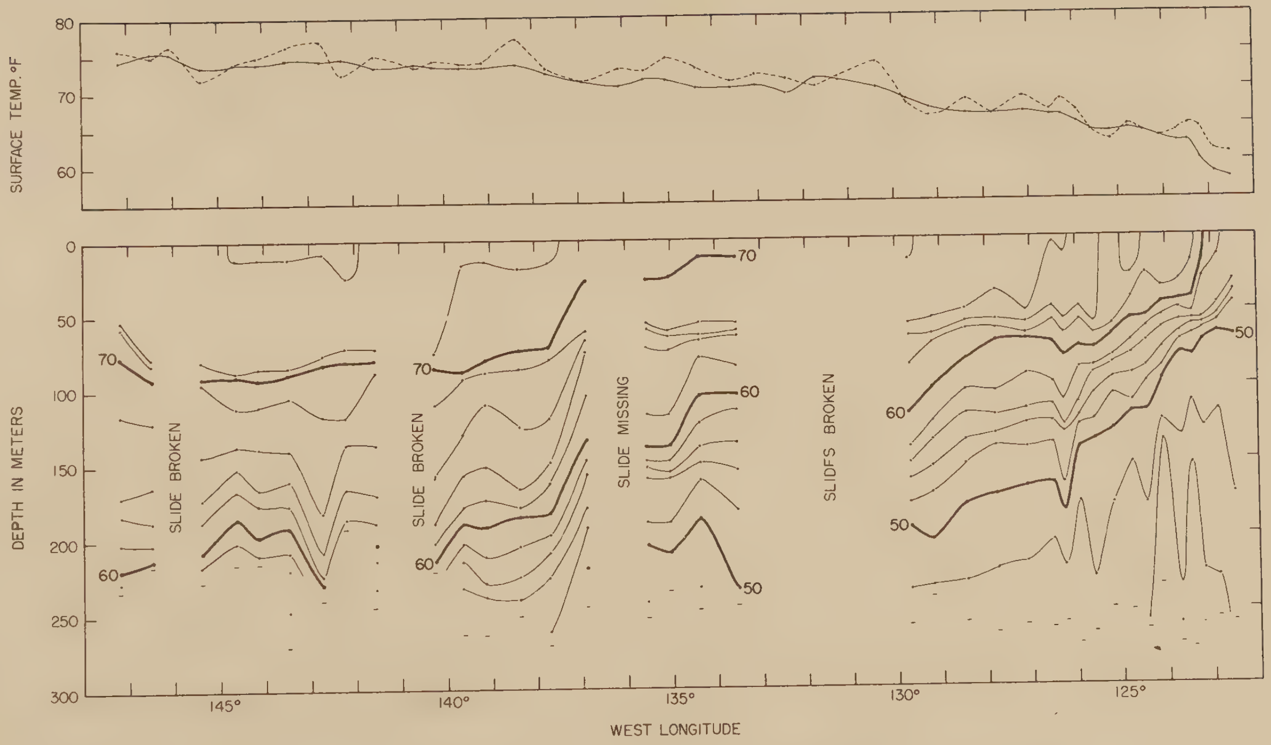
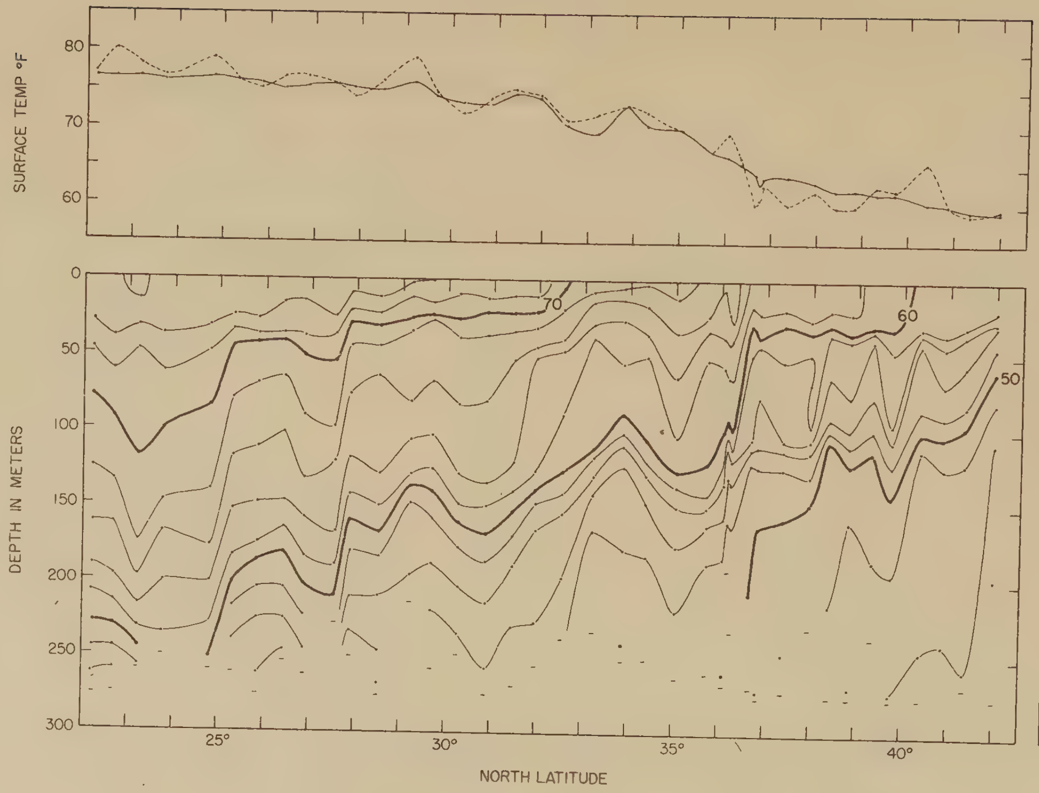


Figure 16.--Temperature sections from BT casts along Section M (see fig. 1), Hugh M. Smith cruise 40 (NEPAS), July 1-September 5, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.



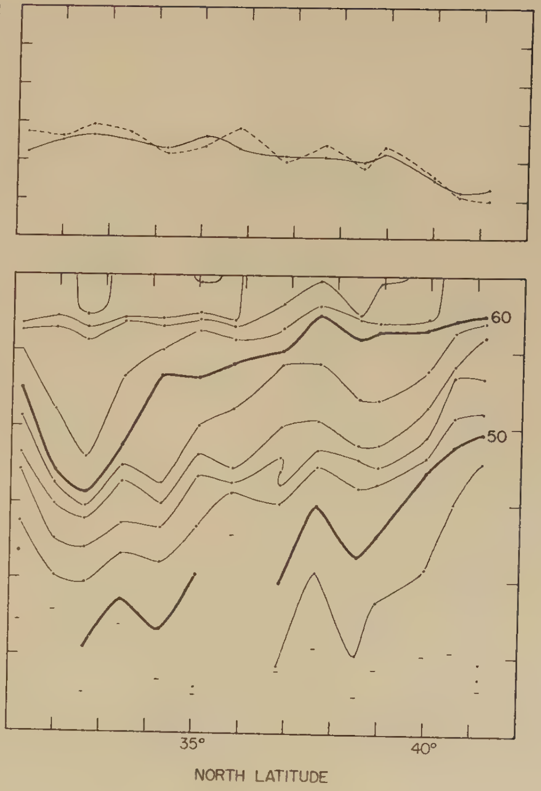
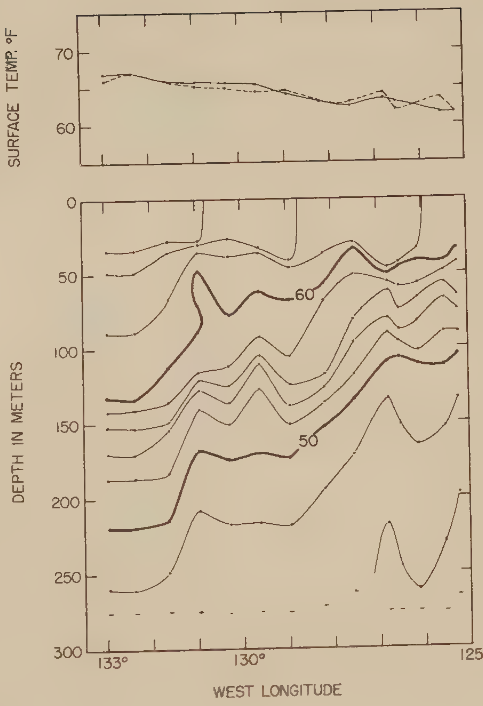
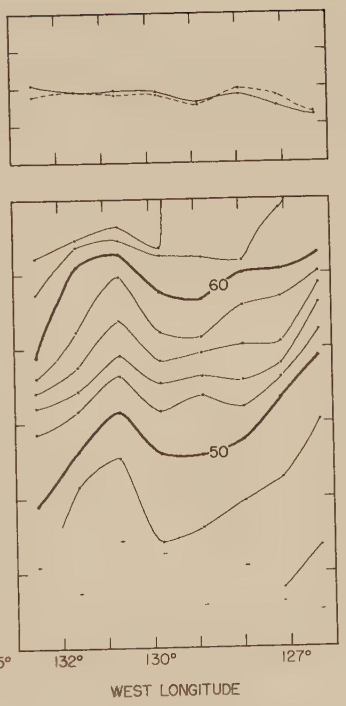
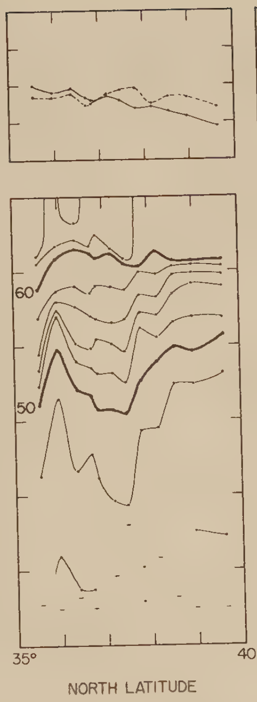


Figure 17.--Temperature sections from BT casts along Section A (see fig. 2), John R. Manning cruise 36 (NEPAS), June 11-August 20, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.

Figure 18.--Same along Section B (fig. 2).







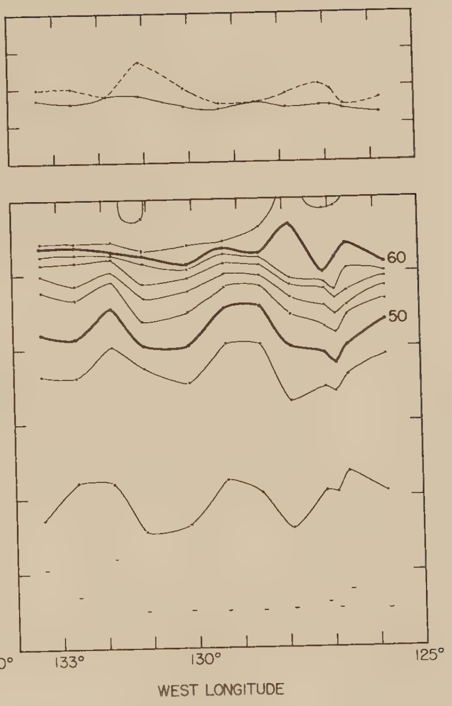
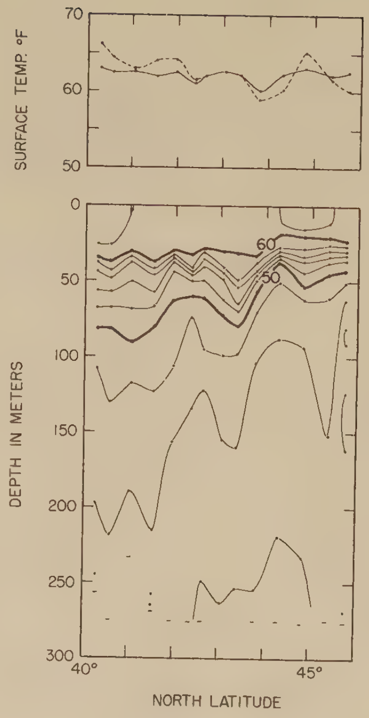


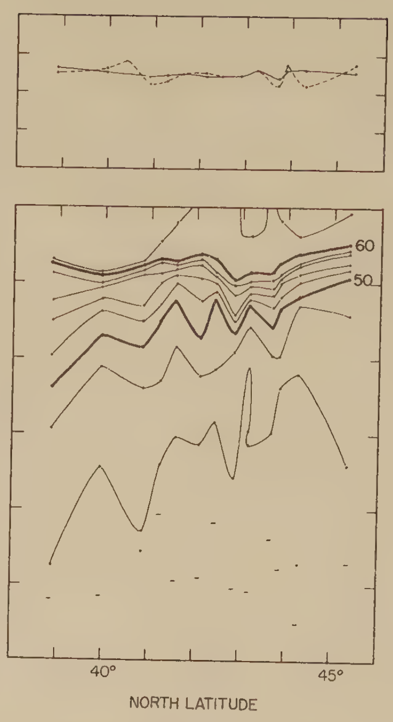
Figure 19.--Temperature sections from BT casts along Section C (see fig. 2), John R. Manning cruise 36 (NEPAS), June 11-August 20, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.

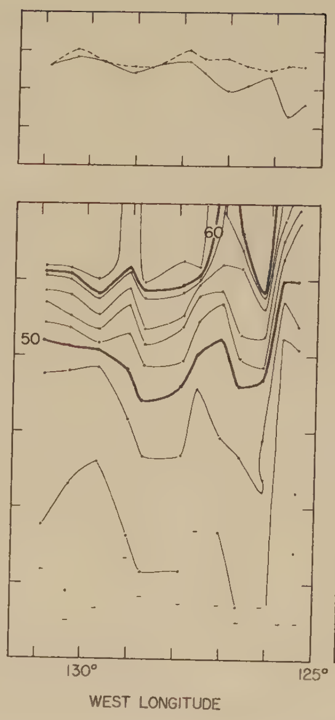
Figure 20.--Same along Section D (fig. 2).

Figure 21.--Same along Section E (fig. 2).

Figure 22.--Same along Section F (fig. 2).







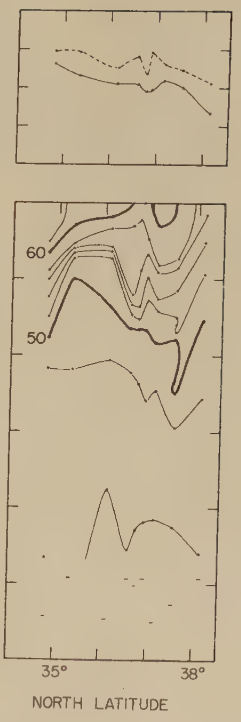


Figure 23.--Temperature sections from BT casts along Section G (see fig. 2), John R. Manning cruise 36 (NEPAS), June 11-August 20, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.

Figure 24.--Same along Section H (fig. 2).

Figure 25.--Same along Section I (fig. 2).

Figure 26.--Same along Section J (fig. 2).

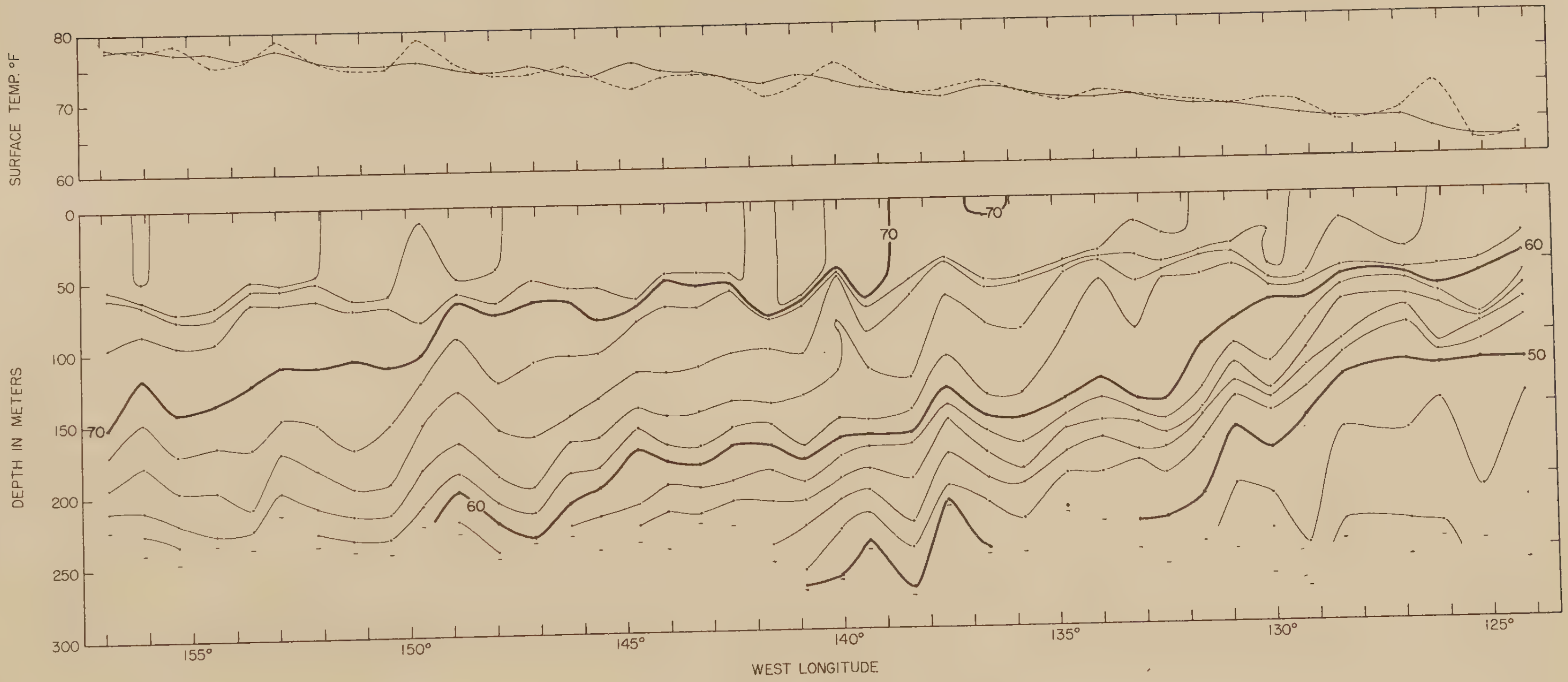


Figure 27.--Temperature sections from BT casts along Section K (see fig. 2), John R. Manning cruise 36 (NEPAS), June 11-August 20, 1957. Upper panel air (dotted) and sea surface (solid) temperatures. Lower panel temperatures from BT slides. Dashes indicate the depth of casts.

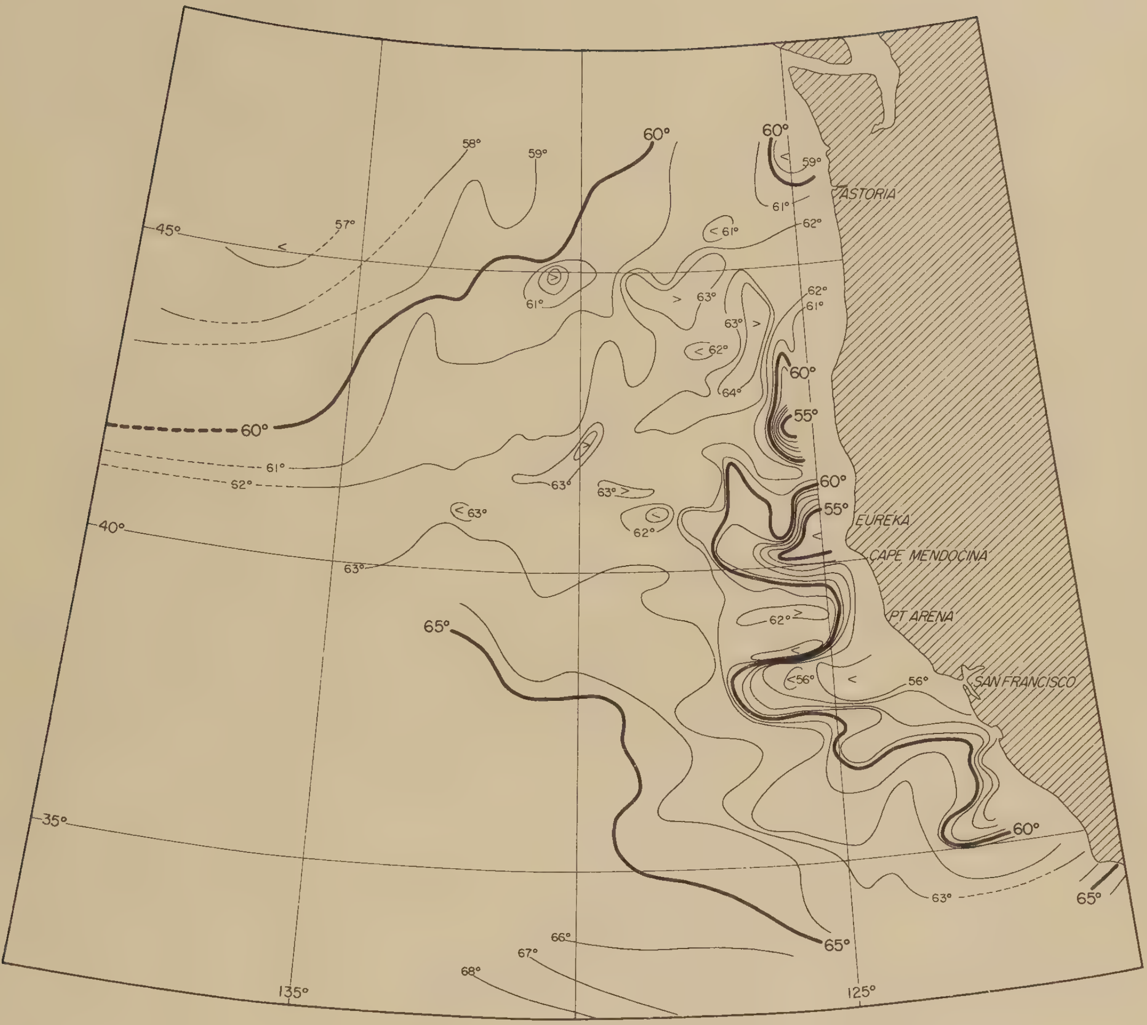

58°
59°
60°
60°
59°
ASTORIA
61°
57°
45°
< 61°
62°
61°
> 63°
62°
61°
63° >
< 62°
60°
64°
55°
60°
61°
62°
63°
63° >
60°
55°
EUREKA
< 63°
62°
40°
63°
CAPE MENDOCINA
PT ARENA
65°
62°
<56°
56°
SAN FRANCISCO
35°
60°
63°
65°
65°
66°
67°
68°
135°
125°

Figure 28.--Sea surface temperature in °F. in the NEPAS area based on observations from Hugh M. Smith cruise 40, July 1-September 5, 1957, John R. Manning cruise 36, June 11-August 20, 1957, and the charter vessels, July 22-August 1, 1957.

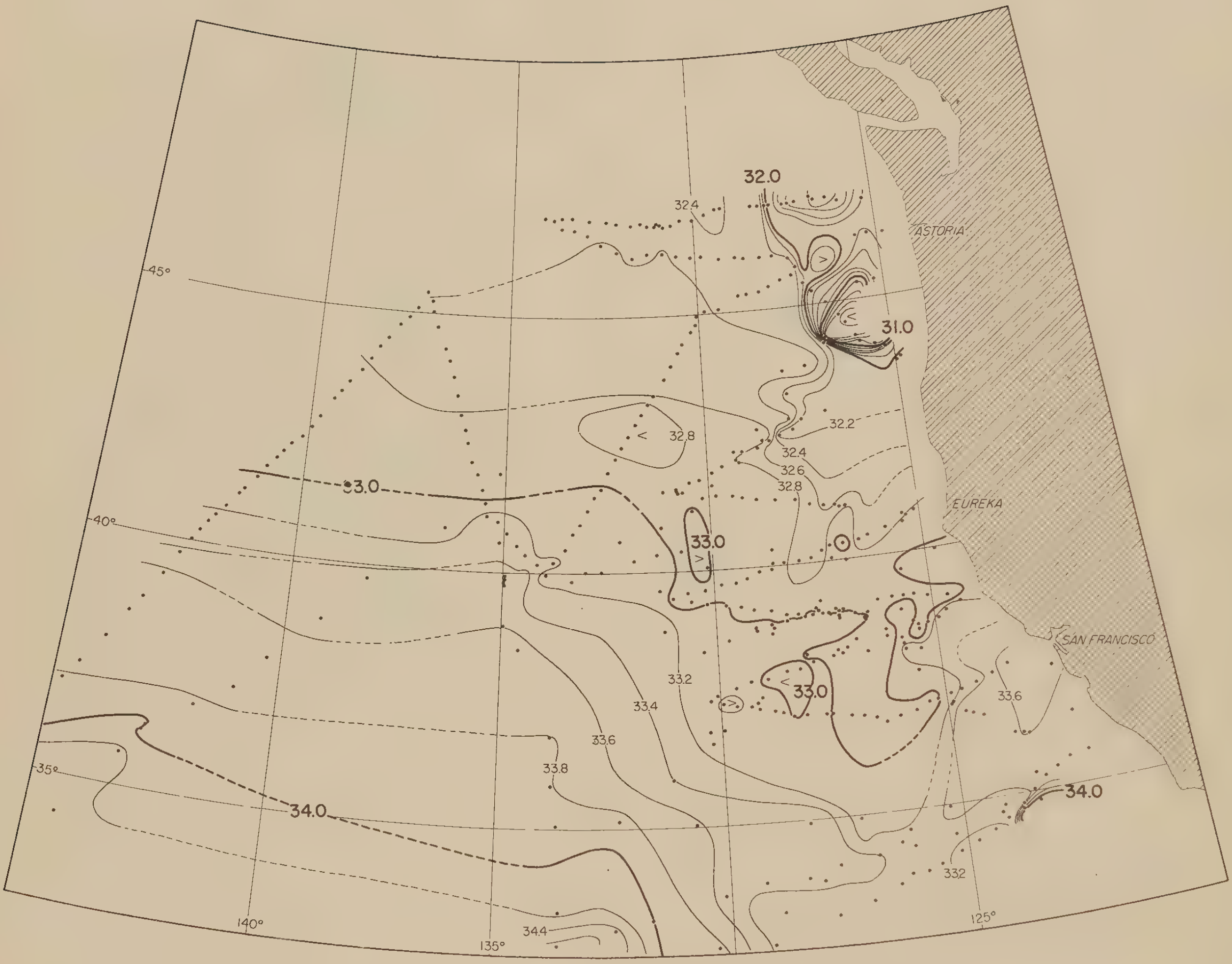

32.0
32.4
ASTORIA
45°
31.0
32.2
32.8
32.4
32.6
32.8
EUREKA
33.0
40°
33.0
SAN FRANCISCO
33.2
33.0
33.6
33.4
33.6
33.8
35°
34.0
34.0
332
140°
34.4
135°
125°

Figure 29.--Surface salinity in ‰ in the NEPAS area based on observations from _Hugh M. Smith_ cruise 40, July 1-September 5, 1957, and _John R. Manning_ cruise 36, June 11-August 20, 1957. Dots indicate observed values. Dashed lines indicate interpolated contours.

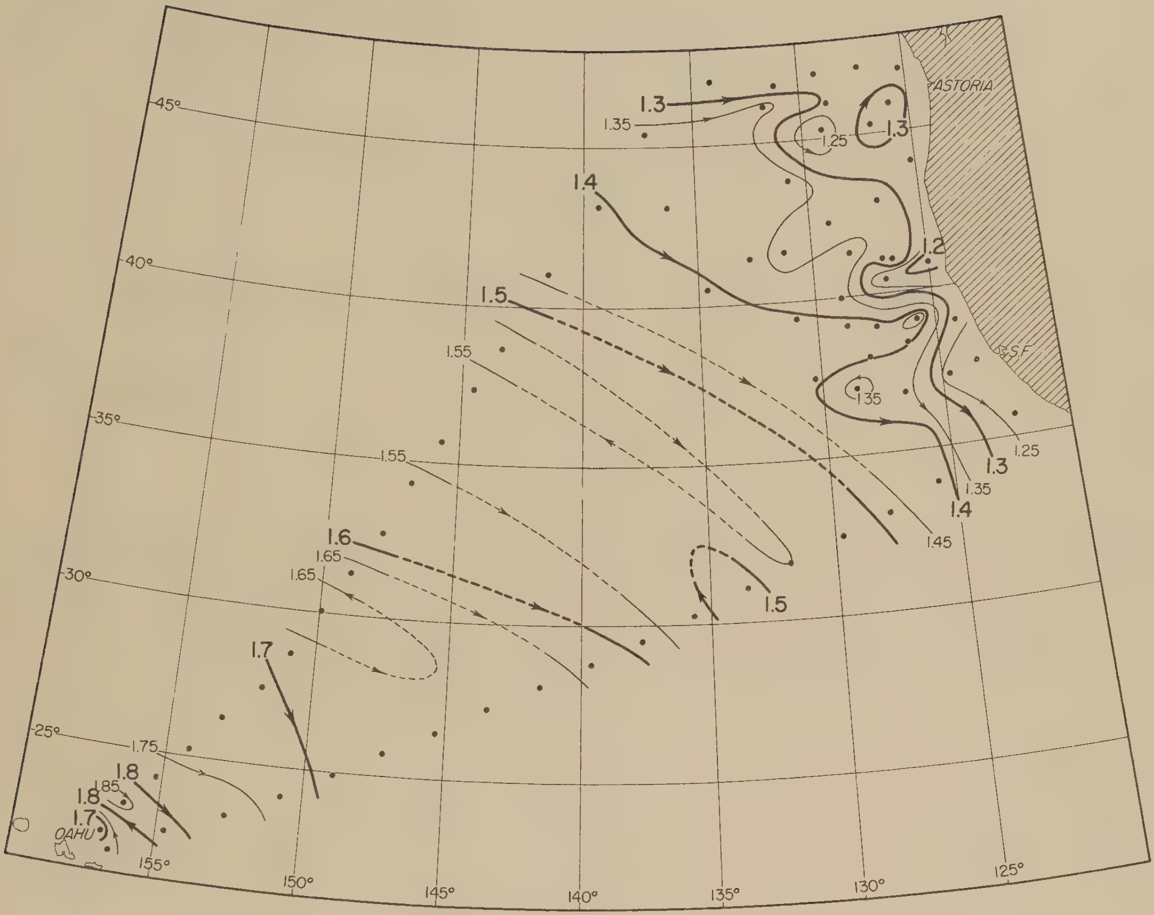

45°
40°
35°
30°
25°
155°
150°
145°
140°
135°
130°
125°
ASTORIA
S.F.
OAHU
1.3
1.35
1.25
1.3
1.4
1.2
1.5
1.55
1.35
1.55
1.25
1.3
1.35
1.4
1.45
1.6
1.65
1.65
1.5
1.7
1.75
1.8
1.85
1.8
1.7

Figure 30.--Anomaly of geopotential topography of the sea surface relative to the 1,000-db. surface, Hugh M. Smith cruise 40 (NEPAS), July 1-September 5, 1957. Dots indicate station positions.

Table 1.--NEPAS charter vessel data

Name	Owner[1]	Home port	Observer	Organization
Allen Cody	Hunter and Foland (L. L. Newton, operator)	Fields Landing, California	Howard O. Yoshida	Honolulu Biological Laboratory
Flicker	Gus Wagner	Newport, Oregon	George Miller	Oregon Fish. Commission
Gypsy	Jim Lyons	Seattle, Washington	William Stickley	Washington Department of Fisheries
Lancing	Oscar Knudsen	Seattle, Washington	None	-
Lynn	Les Withee (Josh Bufton, operator)	Garibaldi, Oregon	None	-
Lynn Ann	Herman Foland	Fields Landing, California	Thomas S. Hida	Honolulu Biological Laboratory
Luwella	O. James Bardeau	San Diego, California	Tom Jow	California Department of Fish and Game
Rowland R. Sr.	William R. Roland	El Cerrito, California	None	-
Tuna Clipper	Erling Kolnes (Floyd M. Rhoades, operator)	San Pedro, California	Robert L. Caldwell	California Department of Fish and Game

[1] Except where operators are indicated, vessels were operated by the owners.

Table 2.--Positions and summary of observations taken at Hugh M. Smith cruise 40 (NEPAS) stations, July 1 - September 5, 1957[1]

Station No.	Time GCT	Date 1957	Position Latitude North	 Longitude West	Hydro. cast	P	SD (m)	WC	UWB No.
1	1818	7/2	22°21'	156°55'	x	-	-	-	-
2	2330	7/2	22°37'	156°43'	-	15	-	-	-
3	0620	7/3	23°12'	156°16'	-	30	-	-	-
4	1820	7/3	24°17'	155°11'	x	-	24	2	-
5	2339	7/3	24°40'	154°47'	-	15	-	-	-
6	0630	7/4	25°15'	154°06'	x	30	-	-	-
7	1814	7/4	26°20'	153°01'	x	-	26	3	-
8	2319	7/4	26°45'	152°35'	-	15	-	-	-
9	0620	7/5	27°25'	151°50'	x	30	-	-	-
10	1810	7/5	28°41'	150°54'	x	-	-	-	-
11	2317	7/5	29°11'	150°32'	-	15	-	-	-
12	0615	7/6	30°02'	149°56'	x	30	-	-	-
13	1720	7/6	31°16'	148°54'	x	-	33	0-1	-
14	2209	7/6	31°47'	148°31'	-	15	-	-	-
15	0510	7/7	32°44'	147°49'	x	-	-	-	-
16	0705	7/7	32°51'	147°45'	-	30	-	-	-
17	1714	7/7	34°12'	146°44'	x	-	35	1	-
18	2214	7/7	34°46'	146°19'	-	15	-	-	-
19	0512	7/8	35°46'	145°38'	x	-	-	-	-
20	0704	7/8	35°52'	145°33'	-	30	-	-	-
21	1712	7/8	37°17'	144°28'	x	-	30	3	-
22	2214	7/8	37°53'	144°00'	-	15	-	-	-
23	0552	7/9	38°47'	143°20'	x	30	-	-	-
24	2200	7/9	40°27'	142°06'	-	15	16-1/2	3	-
25	0543	7/10	41°03'	141°30'	x	30	-	-	-
26	1053	7/10	41°32'	141°00'	-	15	-	-	-
27	2202	7/10	42°24'	140°06'	-	15	16	4	-
28	0545	7/11	43°09'	139°25'	x	30	-	-	-
29	1222	7/11	43°52'	138°44'	-	15	-	-	-
30	2256	7/11	44°43'	137°53'	-	15	22	3	-
31	0545	7/12	45°24'	137°12'	x	30	-	-	-
32	2333	7/12	43°46'	136°24'	-	15	-	-	-
33	0525	7/13	43°03'	136°10'	x	30	-	-	-
34	2154	7/13	41°10'	135°20'	-	15	-	-	-
35	0615	7/14	40°33'	134°37'	x	30	-	-	-
36	2121	7/14	40°43'	133°18'	-	15	27	2	-
37	0505	7/15	41°29'	132°46'	x	30	-	-	-
38	2146	7/15	43°04'	131°34'	-	15	19	2	-
39	0334	7/16	43°33'	131°09'	-	15	-	-	-
40	0501	7/16	43°45'	130°59'	x	30	-	-	-
41	1911	7/16	44°49'	130°02'	-	15	19	3	-
42	2123	7/16	44°57'	130°00'	-	15	17	4	-
43	0458	7/17	45°12'	129°03'	x	30	-	-	-

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[1] P - Surface plankton haul - duration in minutes.
SD - Secchi disc observation in meters
WC - Water color in the Forel scale.
UWB - University of Washington boron samples - number.

Table 2.--Positions and summary of observations taken at Hugh M. Smith cruise 40 (NEPAS) stations, July 1 - September 5, 1957 (cont'd)

Station No.	Time GCT	Date 1957	Position		Hydro. cast	P	SD (m)	WC	UWB No.
			Latitude North	Longitude West					
44	1330	7/17	45°26'	128°06'	-	15	-	-	-
45	2115	7/17	45°41'	127°04'	-	15	-	-	-
46	2312	7/17	45°43'	126°48'	-	15	-	-	-
47	0455	7/18	45°54'	125°57'	x	30	-	-	-
Astoria									
48	1335	7/22	46°54'	125°15'	x	-	-	-	-
49	2128	7/22	47°01'	126°18'	-	15	20	4	-
50	0018	7/23	47°02'	126°35'	-	15	18	4	-
51	0252	7/23	47°02'	126°53'	-	15	-	-	-
52	0534	7/23	47°02'	127°12'	x	30	-	-	-
53	1313	7/23	47°00'	127°07'	-	15	-	-	-
54	1529	7/23	47°00'	127°18'	-	15	17	5	-
55	2007	7/23	47°01'	127°48'	-	15	14	4	-
56	2150	7/23	47°01'	127°48'	-	15	11-1/2	4+	-
57	0505	7/24	47°00'	129°08'	x	30	-	-	-
58	2117	7/24	46°47'	130°22'	-	15	11	3+	-
59	0115	7/25	46°44'	130°49'	-	30	12	4+	-
60	0542	7/25	46°45'	131°04'	x	30	-	-	-
61	0722	7/25	46°46'	130°49'	-	30	-	-	-
62	2124	7/25	46°48'	132°07'	-	15	14	4	-
63	0122	7/26	46°51'	132°46'	-	15	-	-	-
64	0539	7/26	46°55'	133°23'	-	30	-	-	-
65	1210	7/26	46°58'	134°03'	x	-	-	-	-
66	0515	7/27	46°06'	131°40'	x	-	-	-	-
67	2118	7/27	46°06'	130°04'	-	15	16	4	-
68	2325	7/27	46°05'	129°48'	-	15	14	4	-
69	0505	7/28	46°01'	128°55'	x	30	-	-	-
70	2116	7/28	45°58'	127°29'	-	15	12	4+	-
71	0442	7/29	45°15'	126°53'	x	30	-	-	-
72	2147	7/29	44°20'	125°54'	-	15	17	3	-
73	0430	7/30	44°00'	125°07'	x	30	-	-	-
74	2119	7/30	43°18'	126°00'	-	15	18	5	-
75	0445	7/31	42°56'	126°59'	x	15	-	-	-
76	1417	7/31	42°47'	127°15'	-	15	-	-	-
77	1926	7/31	42°36'	127°53'	-	15	-	-	-
78	2111	7/31	42°32'	128°05'	-	15	26	4	-
79	0438	8/1	42°16'	129°05'	x	15	-	-	-
80	2117	8/1	41°48'	130°13'	-	15	23-1/2	2	-
81	0457	8/2	41°33'	131°06'	x	15	-	-	-
82	2119	8/2	41°26'	129°26'	-	15	28	3	-
83	0023	8/3	41°23'	129°03'	-	15	24	2	-
84	0440	8/3	41°18'	128°25'	x	15	-	-	-
85	2135	8/3	41°04'	126°56'	x	15	17	4	-
86	0045	8/4	41°02'	126°41'	x	-	17	4	-
87	0542	8/4	40°58'	126°01'	-	15	-	-	-
88	1740	8/4	40°48'	125°01'	x	15	12	5	-
89	2117	8/4	40°40'	125°19'	-	15	-	-	-
90	2257	8/4	40°37'	125°30'	-	15	-	-	-

Table 2.--Positions and summary of observations taken at Hugh M. Smith cruise 40 (NEPAS) stations, July 1- September 5, 1957 (cont'd)

Station No.	Time GCT	Date 1957	Position		Hydro. cast	P	SD (m)	WC	UWB No.
			Latitude North	Longitude West					
91	0003	8/5	40°34'	125°36'	-	15	-	-	-
92	0517	8/5	40°26'	126°16'	-	15	-	-	-
93	1653	8/5	40°18'	126°54'	x	-	19	3	-
94	2113	8/5	40°12'	127°23'	-	15	15	4	-
95	0534	8/6	40°04'	128°20'	-	15	-	-	-
96	0800	8/6	39°51'	128°57'	x	-	23	2	-
97	2120	8/6	39°45'	129°29'	-	15	27	2	-
98	0532	8/7	39°32'	130°42'	-	15	-	-	-
99	1217	8/7	39°29'	130°58'	x	-	-	-	13
100	2121	8/7	39°17'	129°45'	-	15	25	2	-
101	0425	8/8	39°08'	128°40'	x	15	-	-	-
102	1338	8/8	39°02'	128°21'	-	15	-	-	-
103	1746	8/8	38°59'	127°56'	-	15	-	-	-
104	2235	8/8	39°00'	127°33'	x	15	25	1	-
105	0608	8/9	39°03'	127°01'	-	15	-	-	-
106	2039	8/9	39°11'	125°37'	x	15	21	2	-
107	2308	8/9	39°09'	125°26'	-	15	-	-	-
108	0413	8/10	39°00'	124°35'	-	15	-	-	-
109	0523	8/10	38°57'	124°24'	-	15	-	-	-
110	1210	8/10	38°54'	124°21'	x	-	-	-	-
111	1650	8/10	38°43'	124°47'	-	15	-	-	-
112	1926	8/10	38°37'	125°01'	-	15	20	4	-
113	0046	8/10	38°31'	125°31'	-	15	20	3	-
114	0328	8/11	38°26'	126°01'	-	15	-	-	-
115	0415	8/11	38°26'	126°04'	x	-	-	-	-
116	1749	8/11	39°10'	127°26'	-	15	29	2	-
117	2105	8/11	38°03'	127°51'	x	15	25	2	-
118	0353	8/12	37°53'	128°34'	-	15	-	-	-
119	1305	8/12	37°29'	130°12'	x	15	-	-	-
120	2115	8/12	37°19'	129°20'	-	15	31	1	-
121	2324	8/12	37°16'	129°08'	-	15	-	-	-
122	0202	8/13	37°11'	128°46'	-	15	-	-	-
123	0413	8/13	37°09'	128°31'	x	15	-	-	-
124	1522	8/13	37°02'	128°13'	-	15	-	-	-
125	2110	8/13	37°01'	127°30'	-	15	-	-	-
126	0407	8/14	36°52'	126°35'	x	-	-	-	-
127	2116	8/14	37°01'	125°26'	-	15	-	-	-
128	0125	8/15	37°06'	125°04'	-	15	-	-	-
129	0408	8/15	37°12'	124°41'	x	-	-	-	-
130	1012	8/15	37°26'	123°53'	-	15	-	-	-
131	1213	8/15	37°31'	123°32'	x	-	-	-	-
Oakland									
132	0546	8/26	36°43'	122°25'	-	15	-	-	-
133	1205	8/27	35°39'	122°13'	x	-	-	-	-
134	2113	8/27	35°14'	123°13'	-	15	-	-	-
135	0532	8/27	34°29'	124°17'	-	15	-	-	-
136	1305	8/28	33°54'	125°36'	x	-	-	-	-
137	2115	8/28	33°37'	126°30'	-	15	27	1+	-
138	0405	8/28	33°08'	127°47'	x	30	-	-	-

Table 2.--Positions and summary of observations taken at Hugh M. Smith cruise 40 (NEPAS) stations, July 1- September 5, 1957 (cont'd)

Station No.	Time GCT	Date 1957	Position		Hydro. cast	P	SD (m)	WC	UWB No.
			Latitude North	Longitude West					
139	1605	8/29	32°26'	129°43'	x	-	42	-	-
140	2104	8/29	32°10'	130°28'	-	15	-	-	-
141	0402	8/30	31°43'	131°44'	x	30	-	-	-
142	1605	8/30	31°01'	133°36'	x	-	36	1	-
143	2110	8/30	30°44'	134°20'	-	15	-	-	-
144	0405	8/31	30°14'	135°33'	x	30	-	-	-
145	1704	8/31	29°29'	137°30'	x	-	45	1	-
146	2206	8/31	29°12'	138°23'	-	15	-	-	-
147	0500	9/1	28°45'	139°36'	x	30	-	-	13
148	1706	9/1	28°01'	141°30'	x	-	36	1	-
149	2211	9/1	27°43'	142°13'	-	15	-	-	-
150	0501	9/2	27°16'	143°27'	x	30	-	-	-
151	1704	9/2	26°28'	145°20'	x	-	35	0-1	-
152	1205	9/2	26°10'	146°01'	-	15	-	-	-
153	0501	9/3	25°41'	147°10'	x	30	-	-	-
154	1706	9/3	24°55'	148°00'	x	-	36	1	-
155	1206	9/3	24°38'	149°40'	-	15	-	-	-
156	0601	9/4	24°07'	150°51'	x	30	-	-	13
157	1807	9/4	23°21'	152°41'	x	-	36	1-2	-
158	2308	9/4	23°04'	153°23'	-	15	-	-	-
159	0602	9/5	22°33'	154°39'	x	30	-	-	-
160	1807	9/5	21°45'	156°30'	x	-	31	1	-

Table 3.--Summary of observations at bathythermograph lowerings, *Hugh M. Smith* cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
1	1810	7/2	22°21'N	156°55'W	77.2	080	21	77.7	71.3	1021	02	6	5	8	4	XX	X	-	-
2	2040	7/2	22°21'N	156°55'W	76.7	070	19	78.0	71.2	1021	60	6	5	8	4	XX	X	-	-
3	0010	7/3	22°38'N	156°42'W	76.7	020	19	77.9	71.9	1020	02	6	4	8	4	XX	X	-	-
4	0300	7/3	22°54'N	156°30'W	76.7	040	20	77.0	71.2	1019	01	5,8	2	8	4	040	3	-	-
5	0610	7/3	23°12'N	156°16'W	76.3	060	22	76.8	70.3	1021	03	6,8	7	8	3	XX	X	-	-
6	0730	7/3	23°12'N	156°16'W	76.3	060	22	76.8	70.3	1021	03	6,8	7	8	3	XX	X	-	-
7	1130	7/3	23°34'N	155°53'W	78.0	070	18	75.5	72.1	1019	01	6	7	8	3	XX	X	-	-
8	1505	7/3	23°57'N	155°30'W	76.2	020	15	75.5	71.8	1019	02	8	3	8	3	XX	X	-	-
9	1805	7/3	24°17'N	155°11'W	76.8	060	17	77.2	72.8	1019	02	8	2	9	2	XX	X	-	-
10	1930	7/3	24°17'N	155°11'W	76.7	060	17	77.2	72.8	1019	02	8	2	9	2	060	1	-	-
11	2315	7/3	24°40'N	154°47'W	76.0	060	14	78.8	72.2	1019	02	3,8	3	9	2	060	1	-	-
12	0305	7/4	24°58'N	154°25'W	77.2	080	12	79.8	72.0	1019	02	8,5	2	9	2	080	1	-	-
13	0605	7/4	25°15'N	154°06'W	75.8	080	16	76.7	71.3	1019	02	8	2	9	2	060	1	-	-
14	0735	7/4	25°15'N	154°06'W	75.9	080	11	76.6	71.3	1019	02	8	2	9	2	XX	X	-	-
15	1130	7/4	25°37'N	153°44'W	75.8	090	15	75.4	70.6	1021	02	X	X	9	2	XX	X	-	-
16	1500	7/4	26°00'N	153°21'W	75.8	100	10	72.7	70.1	1021	62	8	7	7	2	050	1	-	-
17	1800	7/4	26°20'N	153°01'W	74.8	070	11	75.3	70.8	1023	02	8	2	9	2	070	1	-	-
18	1910	7/4	26°20'N	153°01'W	75.0	070	13	76.4	70.8	1023	02	5,8	2	9	2	080	1	-	-
19	2305	7/4	26°45'N	152°35'W	75.0	080	15	79.0	72.0	1023	02	5,8	2	9	2	080	1	35.52	-
20	0350	7/5	27°11'N	152°04'W	74.9	060	16	77.7	71.9	1023	03	5,8	4	9	2	070	1	35.39	-
21	0605	7/5	27°25'N	151°50'W	75.9	090	15	76.0	71.0	1024	03	6	6	9	2	070	1	-	-
22	0715	7/5	27°25'N	151°50'W	75.9	070	14	75.3	70.2	1025	02	6	6	9	2	XX	X	-	-
23	1130	7/5	27°53'N	151°30'W	75.1	080	15	73.9	69.2	1025	50	X	X	6	2	XX	X	35.30	-
24	1500	7/5	28°18'N	151°10'W	74.2	040	10	73.3	68.0	1026	00	4,8	6	9	2	050	1	35.28	-
25	1805	7/5	28°41'N	150°54'W	74.4	070	18	73.8	69.6	1026	02	2	8	9	3	060	2	-	-
26	1910	7/5	28°41'N	150°54'W	74.6	070	18	73.8	69.6	1026	02	2	8	9	3	060	3	-	-
27	2305	7/5	29°11'N	150°32'W	74.2	080	14	76.9	70.4	1026	02	1	8	9	2	080	1	35.43	-
28	0300	7/6	29°38'N	150°13'W	74.2	070	17	73.4	67.5	1026	03	4,7,8	8	9	2	070	1	35.43	-
29	0610	7/6	30°02'N	149°56'W	73.8	030	13	72.8	67.2	1026	02	6,8	8	9	2	070	1	-	-
30	0715	7/6	30°02'N	149°56'W	73.6	040	14	71.8	66.8	1026	50	X	X	8	2	XX	X	-	-
31	1130	7/6	30°32'N	149°31'W	72.9	070	20	71.8	67.6	1025	00	X	X	8	2	XX	X	35.25	-
32	1505	7/6	31°00'N	149°08'W	XX X	070	13	72.2	66.4	1026	03	4,0	7	8	2	070	1	35.34	-
33	1710	7/6	31°16'N	148°54'W	72.7	030	13	72.5	65.3	1026	02	8	8	9	2	030	1	-	-
34	1820	7/6	31°16'N	148°54'W	73.7	010	13	72.1	65.7	1026	02	8	8	9	2	020	1	-	-
35	2200	7/6	31°47'N	148°31'W	73.6	050	12	75.6	69.2	1027	02	4,8	7	9	2	030	1	34.97	-

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
36	0205	7/7	32°18'N	148°08'W	73.3	040	13	74.8	68.5	1026	60	4,8	7	9	2	050	1	-	-
37	0510	7/7	32°44'N	147°49'W	73.2	080	07	72.7	68.3	1026	02	8	2	9	2	050	1	-	-
38	0605	7/7	32°44'N	147°49'W	73.0	080	07	72.7	68.3	1026	02	8	2	9	2	050	1	-	-
39	1105	7/7	33°20'N	147°23'W	71.6	060	07	70.2	65.6	1026	01	X	X	8	2	XX	1	34.83	-
40	1400	7/7	33°46'N	147°04'W	71.8	020	06	69.0	65.1	1025	02	8	1	9	1	080	1	34.69	-
41	1710	7/7	34°12'N	146°44'W	71.0	020	08	70.0	65.8	1025	02	8	1	9	1	XX	1	-	-
42	1810	7/7	34°12'N	146°44'W	70.9	020	08	70.0	65.8	1025	02	8	1	9	1	030	1	-	-
43	2205	7/7	34°46'N	146°19'W	75.4	030	03	73.6	66.0	1026	02	5,8	1	9	1	010	1	34.42	-
44	0205	7/8	35°21'N	145°55'W	74.1	250	05	73.8	67.2	1025	01	8	1	9	1	140	1	34.47	-
45	0500	7/8	35°46'N	145°38'W	71.9	260	07	71.9	67.5	1025	03	8	2	9	1	XX	X	-	-
46	0605	7/8	35°46'N	145°38'W	71.3	250	09	71.3	66.8	1025	03	8	2	9	1	XX	X	-	0.40
47	1105	7/8	36°23'N	145°10'W	69.0	260	15	69.8	67.7	1024	02	8	2	9	2	XX	X	34.23	-
48	1400	7/8	36°50'N	144°49'W	68.6	250	09	69.2	66.0	1023	01	5,6	7	8	2	300	1	33.87	-
49	1705	7/8	37°17'N	144°28'W	68.3	270	10	68.7	66.6	1023	02	2,8	1	9	2	290	1	-	-
50	1805	7/8	37°17'N	144°28'W	68.3	270	10	68.7	66.6	1023	02	2,8	1	9	2	290	1	-	-
51	2205	7/8	37°53'N	144°00'W	67.2	210	13	72.1	69.2	1022	03	2,8	2	9	2	300	1	33.75	-
52	0200	7/9	38°27'N	143°35'W	66.4	230	16	69.6	67.1	1021	02	3,6	7	8	2	270	1	33.69	-
53	0510	7/9	38°47'N	143°20'W	66.0	240	20	68.1	67.0	1019	03	4,8	8	8	3	260	2	-	0.37
53A	0650	7/9	38°47'N	143°20'W	66.0	230	22	67.8	66.3	1019	63	8	8	8	3	260	2	-	-
54	1100	7/9	39°18'N	142°59'W	64.5	260	23	66.8	65.2	1016	63	X	8	6	3	270	3	33.66	-
55	1400	7/9	39°44'N	142°40'W	63.4	350	18	64.5	63.0	1015	02	8,0	8	7	3	250	3	33.49	-
56	1715	7/9	40°01'N	142°28'W	63.7	010	14	64.2	62.7	1015	02	8,6,0	8	7	3	250	3	33.21	-
57	1915	7/9	40°13'N	142°18'W	63.3	250	10	63.9	62.3	1015	02	8,0	7	9	3	240	3	33.28	-
58	2130	7/9	40°26'N	142°08'W	63.1	250	10	64.0	62.2	1015	02	0,6,8	8	9	3	240	3	33.21	0.10
59	0000	7/10	40°35'N	141°57'W	62.1	030	25	61.7	58.9	1017	15	0,6	8	7	3	010	3	33.21	0.34
60	0235	7/10	40°48'N	141°45'W	62.5	030	24	60.8	57.8	1017	02	8,0,6	8	7	3	030	3	33.19	0.16
61	0535	7/10	41°03'N	141°30'W	62.4	020	21	62.3	60.0	1020	00	X	7	8	4	020	3	-	0.36
62	0645	7/10	41°03'N	141°30'W	62.4	020	21	62.3	60.0	1020	00	X	7	8	4	020	3	-	-
63	0830	7/10	41°10'N	141°22'W	61.5	020	18	59.6	55.9	1021	02	X	7	8	4	020	3	33.17	-
64	1005	7/10	41°26'N	141°05'W	60.5	030	15	58.0	52.3	1021	01	8	2	7	3	XX	X	33.01	-
65	1200	7/10	41°38'N	140°54'W	60.2	000	12	57.5	52.2	1021	01	8	2	7	3	XX	X	32.97	-
66	1400	7/10	41°49'N	140°42'W	59.4	340	13	57.7	54.5	1021	03	4,8	4	9	3	010	1	32.97	0.20
67	1635	7/10	42°01'N	140°31'W	59.0	030	14	57.7	54.8	1022	03	6,8	6	9	3	010	1	33.01	0.35
68	1900	7/10	42°12'N	140°19'W	59.0	350	14	57.7	53.2	1023	02	6,8	7	9	3	010	1	32.94	-
69	2135	7/10	42°23'N	140°07'W	59.9	350	05	59.0	56.0	1023	01	6,8	6	9	2	010	1	32.95	0.31

Table 3.--Summary of observations at bathythermograph lowerings, *Hugh M. Smith* cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
70	0000	7/11	42°35'N	139°56'W	59.5	350	11	58.6	56.0	1023	03	6,8,0	7	9	2	010	1	32.84	0.38
71	0235	7/11	42°49'N	139°44'W	60.3	320	09	57.6	57.2	1022	02	6	7	9	2	010	1	32.94	0.22
72	0535	7/11	43°09'N	139°25'W	59.2	280	10	57.5	53.6	1023	03	6	8	9	2	330	1	-	0.41
73	0645	7/11	43°09'N	139°25'W	59.0	280	10	57.5	53.6	1023	03	6	8	9	2	330	1	-	-
74	0830	7/11	43°21'N	139°15'W	58.7	270	10	57.8	55.8	1022	03	6,8	8	7	2	XX	1	32.86	0.24
75	1000	7/11	43°32'N	139°03'W	58.4	260	10	57.0	53.9	1021	02	6,8	8	8	3	XX	X	32.90	0.30
76	1210	7/11	43°49'N	138°47'W	57.8	250	11	57.7	53.5	1021	02	6,8	8	8	3	XX	X	32.88	0.62
77	1400	7/11	44°02'N	138°33'W	57.8	220	07	56.8	54.0	1020	02	6,8	8	9	2	310	1	32.75	0.34
78	1630	7/11	44°16'N	138°20'W	56.9	220	10	57.0	54.5	1020	02	6,8	8	9	3	310	1	32.74	0.39
79	1900	7/11	44°29'N	138°07'W	57.5	230	10	59.0	53.0	1018	02	6,8	8	9	3	310	1	32.72	0.32
80	2135	7/11	44°42'N	137°54'W	57.6	220	14	60.1	56.3	1021	02	6,8	8	9	2	310	1	32.66	0.55
81	0000	7/12	44°54'N	137°42'W	57.0	160	14	60.1	57.2	1020	02	6,8	8	9	2	350	2	32.74	0.44
82	0230	7/12	45°07'N	137°29'W	57.0	130	11	58.0	57.9	1015	50	6,8	8	8	2	340	2	32.68	0.57
83	0535	7/12	45°24'N	137°12'W	56.9	150	14	56.9	56.4	1013	50	6,8	8	8	2	340	2	-	0.59
84	0650	7/12	45°24'N	137°12'W	56.8	150	14	56.9	56.9	1013	50	6,8	8	8	2	340	2	-	-
85	0845	7/12	45°15'N	137°07'W	56.9	130	23	57.4	57.3	1012	50	X	X	8	3	XX	X	32.66	0.47
86	1000	7/12	45°03'N	137°01'W	56.8	130	22	57.3	57.2	1009	61	X	X	6	3	XX	X	32.68	0.43
87	1200	7/12	44°48'N	136°53'W	57.0	080	26	57.0	57.0	1006	63	X	X	6	4	XX	X	32.72	0.42
88	1705	7/12	44°22'N	136°38'W	57.3	090	26	57.8	57.7	1002	63	6,8	8	6	5	150	3	32.61	0.49
89	2010	7/12	44°06'N	136°31'W	57.7	250	13	60.8	59.0	XXX	01	6,8	7	9	4	080	3	32.86	0.40
90	2300	7/12	43°48'N	136°24'W	58.7	240	11	59.1	58.5	1001	42	6,8	8	7	3	180	3	32.77	0.37
91	0235	7/13	43°24'N	136°17'W	59.5	150	07	61.8	59.0	1002	07	6,8	7	7	3	160	3	32.77	0.37
92	0515	7/13	43°03'N	136°10'W	59.3	310	06	61.3	58.9	1002	03	6,8	8	9	3	XX	X	-	NS
93	0620	7/13	43°03'N	136°10'W	59.3	310	06	61.3	58.9	1002	03	6,8	8	9	3	XX	X	-	-
94	0830	7/13	42°45'N	136°02'W	59.5	300	06	62.5	60.8	1003	02	6,8	8	8	3	XX	X	32.88	0.37
95	1000	7/13	42°30'N	135°56'W	59.7	290	10	62.5	59.0	1004	02	6,8	8	7	3	XX	X	32.88	0.49
96	1200	7/13	42°09'N	135°48'W	60.2	290	10	61.2	58.2	1004	02	6,8	8	7	3	XX	1	32.88	0.35
97	1405	7/13	41°52'N	135°40'W	60.3	320	22	61.0	57.8	1005	02	6,8	8	8	4	310	4	32.88	0.37
98	1645	7/13	41°37'N	135°33'W	60.9	320	21	61.2	58.0	1007	50	6,8	8	8	4	310	4	32.94	0.76
99	1900	7/13	41°23'N	135°28'W	61.6	320	25	61.2	57.4	1010	02	6,8	8	9	4	310	4	33.01	0.36
100	2130	7/13	41°10'N	135°20'W	62.3	310	19	60.8	58.2	1011	01	6,8	5	9	4	310	4	33.22	0.37
101	0000	7/14	40°59'N	135°08'W	62.7	340	21	62.8	58.0	1012	01	6,8	4	9	4	330	4	33.26	0.33
102	0230	7/14	40°47'N	134°53'W	62.8	310	21	63.2	58.7	1012	02	8	4	9	4	310	4	33.30	0.27
103	0510	7/14	40°34'N	134°39'W	62.7	290	17	61.8	59.2	1016	02	8	4	9	4	310	4	-	0.50
104	0720	7/14	40°33'N	134°37'W	62.7	290	17	61.8	59.2	1016	02	8	4	9	4	310	4	-	-

Table 3. -- Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO$_4$-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
105	0900	7/14	40°23'N	134°26'W	62.7	270	08	63.2	60.0	1017	02	X	X	9	4	XX	4	33.26	0.35
106	1100	7/14	40°08'N	134°10'W	62.9	300	06	64.2	59.8	1017	02	6,8	2	9	3	XX	X	33.21	0.36
107	1300	7/14	39°58'N	133°59'W	62.8	310	19	62.4	57.5	1019	02	6,8	7	9	3	320	1	33.19	0.43
108	1530	7/14	40°12'N	133°45'W	62.9	300	15	62.2	57.0	1020	16	6,8	8	8	3	320	2	33.21	-
109	1830	7/14	40°29'N	133°30'W	62.6	320	09	62.1	59.8	1022	03	6,8	8	9	3	080	1	33.08	0.30
110	2100	7/14	40°43'N	133°18'W	62.7	330	15	62.5	58.2	1023	02	6,8	8	9	3	070	2	33.06	0.43
111	2330	7/14	40°55'N	133°10'W	62.3	310	09	62.3	56.6	1024	01	6,8	6	9	3	310	2	33.04	0.47
112	0200	7/15	41°12'N	132°58'W	62.2	320	12	62.0	58.0	1024	02	6,8	7	9	3	260	1	33.01	0.35
113	0500	7/15	41°29'N	132°46'W	61.8	280	10	60.0	58.8	1025	02	6,8	7	9	3	270	2	-	0.49
114	0605	7/15	41°29'N	132°46'W	61.7	280	10	60.0	58.8	1025	02	6,8	7	9	3	270	2	-	-
115	0800	7/15	41°40'N	132°38'W	61.3	310	12	60.8	58.3	1026	02	X	X	9	3	XX	X	33.01	0.11
116	1000	7/15	41°57'N	132°27'W	60.8	300	15	61.1	57.7	1026	00	X	X	9	3	XX	X	32.94	0.49
117	1200	7/15	42°14'N	132°15'W	61.2	310	19	60.6	59.2	1026	00	X	X	9	3	XX	X	32.88	0.49
118	1400	7/15	42°27'N	132°05'W	60.8	330	17	60.2	56.0	1026	02	6,8	8	9	3	270	1	33.68	0.52
119	1630	7/15	42°41'N	131°54'W	60.9	320	12	59.7	55.1	1027	50	6,8	8	8	3	320	2	32.77	0.49
120	1835	7/15	42°52'N	131°44'W	60.8	290	09	58.7	55.4	1027	02	6,8	8	9	2	310	2	32.74	0.77
121	2113	7/15	43°05'N	131°33'W	61.0	330	17	59.6	57.0	1028	01	6,8	5	9	2	310	2	32.83	0.63
122	2330	7/15	43°12'N	131°27'W	60.5	330	18	60.0	58.1	1027	02	6,8	5	9	3	340	1	32.74	0.49
123	0200	7/16	43°25'N	131°16'W	60.5	330	16	59.8	58.0	1027	01	6,8	4	9	3	340	2	32.83	0.40
124	0450	7/16	43°45'N	130°59'W	59.8	350	16	59.4	58.2	1028	02	6,8	4	9	3	XX	X	-	0.57
125	0600	7/16	43°45'N	130°59'W	59.8	350	16	59.4	58.2	1028	02	6,8	4	9	3	XX	X	-	-
126	0900	7/16	44°00'N	130°47'W	59.6	310	20	58.8	56.0	1028	02	6,8	4	9	3	XX	X	32.81	-
127	1200	7/16	44°16'N	130°35'W	58.9	350	16	57.9	56.1	1028	01	8	3	9	3	XX	X	32.75	0.41
128	1400	7/16	44°28'N	130°26'W	59.0	350	19	57.9	56.9	1028	02	8	3	9	3	350	1	32.74	0.52
129	1630	7/16	44°38'N	130°13'W	58.8	350	19	58.2	57.3	1029	02	6,8	5	9	3	360	1	32.74	0.55
130	1830	7/16	44°46'N	130°06'W	58.6	360	20	58.9	57.1	1029	03	4,6,8	7	9	3	360	1	32.72	0.51
131	2100	7/16	44°56'N	130°01'W	58.8	000	20	59.3	57.3	1030	03	4,6,8	6	9	3	300	1	32.68	0.43
132	2330	7/16	45°02'N	129°48'W	58.8	290	26	59.3	56.4	1029	01	4,6,8	5	9	3	300	1	32.63	0.56
133	0200	7/17	45°06'N	129°27'W	59.2	340	24	59.8	58.1	1028	01	6,8	6	9	3	340	1	32.57	0.50
134	0500	7/17	45°11'N	129°06'W	60.2	320	24	58.8	57.6	1029	02	6,8	6	9	3	340	2	-	0.45
135	0605	7/17	45°12'N	129°03'W	60.1	320	24	58.8	57.6	1029	02	6,8	6	9	3	340	2	-	-
136	0900	7/17	45°17'N	128°42'W	60.1	350	18	59.0	57.3	1028	03	6,8	7	9	3	XX	X	32.38	0.50
137	1200	7/17	45°21'N	128°18'W	61.0	350	18	58.2	57.0	1027	02	6,8	8	9	3	350	1	32.07	0.36
138	1400	7/17	45°27'N	128°02'W	61.2	350	22	58.7	57.1	1026	03	0,8	8	9	3	350	1	31.98	0.39
139	1630	7/17	45°33'N	127°42'W	61.3	320	19	58.8	52.6	1026	02	6,8	8	9	3	350	1	31.71	0.50

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
140	1830	7/17	45°37'N	127°26'W	61.3	330	19	59.7	56.4	1025	02	6,8	7	9	3	350	1	31.67	0.48
141	2105	7/17	45°41'N	127°04'W	60.9	320	21	59.8	56.8	1024	02	6,8	8	9	3	270	1	31.74	0.40
142	2330	7/17	45°44'N	126°45'W	60.1	340	20	60.2	57.3	1023	01	6,8	7	9	4	340	3	32.52	0.51
143	0215	7/18	45°47'N	126°21'W	61.2	330	20	60.3	55.8	1022	02	6,8	8	9	4	340	2	32.36	-
144	0445	7/18	45°54'N	125°58'W	61.7	340	19	60.7	58.3	1021	01	6,8	4	9	4	320	4	-	0.47
145	0605	7/18	45°54'N	125°57'W	61.7	340	19	60.7	58.3	1021	01	6,8	4	9	4	320	4	-	-
146	1205	7/18	46°16'N	125°31'W	60.5	320	20	59.9	58.0	1019	01	6,8	3	9	3	320	4	31.83	0.40
147	1405	7/18	46°15'N	125°12'W	60.9	320	17	60.8	58.3	1019	01	6,8	2	9	3	320	4	31.64	0.30
148	1630	7/18	46°14'N	124°48'W	60.9	010	21	54.0	57.2	1018	02	6,8	2	9	3	320	3	31.92	0.41
149	1330	7/22	46°54'N	125°15'W	58.2	320	07	58.5	57.8	1017	02	0	8	8	2	320	1	-	0.52
150	1430	7/22	46°54'N	125°15'W	58.1	320	07	58.5	57.8	1017	02	0	8	8	2	320	1	-	-
151	1630	7/22	46°59'N	125°34'W	60.9	300	04	60.6	59.8	1017	02	0,6	8	8	2	300	1	31.40	0.34
152	1830	7/22	46°59'N	125°53'W	61.1	210	06	59.4	56.2	1017	02	0,6	8	8	2	330	1	31.24	0.27
153	2115	7/22	47°01'N	126°18'W	61.5	230	14	62.2	61.2	1017	02	0,8,6	6	9	2	310	1	30.97	0.10
154	2330	7/22	47°01'N	126°32'W	61.8	250	13	62.8	60.3	1017	02	0,8,6	6	9	2	310	1	31.15	0.30
155	0120	7/23	47°02'N	126°41'W	61.8	260	15	62.5	60.0	1017	01	8,6	4	9	2	280	1	31.40	-
156	0217	7/23	47°02'N	126°48'W	61.8	260	15	62.2	60.1	1017	03	8,6	7	9	2	280	1	31.65	0.41
157	0450	7/23	47°02'N	127°08'W	61.2	280	10	60.5	57.2	1019	02	X	X	8	2	280	1	-	-
158	0630	7/23	47°02'N	127°12'W	60.9	260	16	62.3	58.6	1020	02	X	X	9	2	XX	X	-	0.40
159	1240	7/23	47°00'N	127°04'W	60.9	280	05	60.2	59.1	1023	60	0,1,6	6	9	2	280	1	30.81	0.30
160	1515	7/23	47°00'N	127°18'W	61.0	280	05	59.5	59.0	1024	01	6,8	5	9	2	280	1	31.38	0.30
161	1830	7/23	47°00'N	127°24'W	61.2	270	09	62.0	58.8	1025	01	6,8	3	9	2	270	1	31.44	0.30
162	1950	7/23	47°01'N	127°47'W	61.2	270	05	62.0	58.6	1025	01	6,8	3	9	2	270	1	31.71	0.33
163	2130	7/23	47°00'N	127°59'W	59.8	270	10	62.8	60.9	1026	02	6,8	3	9	1	240	1	32.38	0.50
164	2330	7/23	47°00'N	128°13'W	60.3	270	07	61.7	60.2	1026	01	6,8	2	9	1	250	2	32.45	0.43
165	0210	7/24	47°00'N	128°39'W	59.7	270	08	61.2	59.2	1025	03	6,8	7	9	1	270	2	32.50	0.52
166	0455	7/24	47°00'N	129°08'W	59.2	270	06	59.0	58.5	1025	02	0,5	7	9	1	270	2	-	-
167	0600	7/24	47°00'N	129°08'W	59.2	260	07	59.8	58.1	1026	02	0,5	7	9	1	270	2	-	0.44
168	1245	7/24	47°01'N	129°10'W	58.8	270	07	59.0	56.8	1025	01	6	3	9	1	270	2	32.18	0.43
169	1400	7/24	47°00'N	129°21'W	58.7	270	09	59.7	57.0	1025	01	6	2	9	1	270	2	32.34	0.44
170	1630	7/24	46°55'N	129°43'W	58.7	260	10	59.1	57.9	1025	03	0,6	8	9	1	290	2	32.34	0.54
171	1830	7/24	46°51'N	130°01'W	58.7	250	10	60.3	59.7	1025	02	0,6	8	9	1	290	4	32.41	-
172	2100	7/24	46°47'N	130°22'W	59.1	240	11	60.4	59.3	1025	03	0,3	4	9	1	280	2	32.50	0.35
173	2330	7/24	46°44'N	130°38'W	59.0	240	12	60.0	58.5	1024	02	4,8	8	9	2	280	2	32.50	0.52
174	0050	7/25	46°43'N	130°49'W	59.1	240	06	61.5	61.0	1023	02	4	8	9	2	XX	X	32.54	0.59

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
175	0055	7/25	46°43'N	130°49'W	59.1	240	06	61.5	61.0	1023	02	4	8	9	2	XX	X	-	-
176	0300	7/25	46°44'N	130°55'W	59.0	220	13	60.2	59.0	1021	02	0, 8	7	9	2	260	2	32.48	0.50
177	0425	7/25	46°45'N	131°04'W	58.9	220	14	59.6	59.0	1021	02	1, 2	8	9	2	260	2	-	0.47
178	0535	7/25	46°45'N	131°04'W	59.0	200	13	61.8	60.2	1020	02	X	X	9	2	XX	X	-	-
179	1300	7/25	46°46'N	131°01'W	58.7	280	19	59.1	58.3	1018	02	0, 6, 8	4	9	3	280	1	32.48	0.50
180	1445	7/25	46°46'N	131°14'W	58.7	330	18	58.0	57.1	1019	03	0, 6, 8	6	9	4	280	3	32.52	0.52
181	1630	7/25	46°46'N	131°28'W	58.3	300	20	59.2	56.5	1020	03	6, 4, 8	6	9	4	280	3	32.48	0.47
182	1830	7/25	46°47'N	131°45'W	58.1	300	20	59.9	57.0	1021	02	4, 6, 8	8	9	3	280	3	32.47	0.51
183	2105	7/25	46°48'N	132°07'W	58.2	290	17	59.6	57.9	1022	01	4, 8	2	9	3	280	3	32.52	0.58
184	2330	7/25	46°50'N	132°27'W	58.5	280	26	59.8	56.2	1022	03	6, 8	6	9	3	280	3	32.57	0.61
185	0200	7/26	46°52'N	132°51'W	57.9	280	24	58.2	56.0	1023	02	0, 1, 4, 8	7	9	3	280	3	32.54	0.60
186	0530	7/26	46°55'N	133°23'W	57.7	280	10	57.8	55.0	1026	02	0, 1, 4, 8	5	9	3	280	3	32.54	0.52
187	0800	7/26	46°56'N	133°37'W	57.4	280	09	58.0	54.8	1022	00	X	X	9	3	XX	X	32.52	0.61
188	1000	7/26	46°56'N	133°50'W	57.4	280	14	57.0	56.4	1022	00	X	X	9	3	XX	X	32.52	0.60
189	1200	7/26	46°58'N	134°02'W	57.3	260	20	55.0	54.2	1022	00	X	X	9	3	XX	X	-	0.51
190	1315	7/26	46°57'N	134°02'W	57.3	260	20	55.0	54.2	1022	63	0, 6	8	9	3	XX	X	-	-
191	1630	7/26	46°48'N	133°34'W	57.8	130	27	59.2	59.0	1019	63	0, 6	8	8	3	050	3	32.59	0.50
192	1830	7/26	46°42'N	133°17'W	57.9	210	18	60.0	59.5	1019	63	0, 6, 8	8	8	3	230	3	32.56	-
193	2100	7/26	46°34'N	132°55'W	58.9	210	17	61.6	61.0	1018	53	0	8	5	4	240	3	32.54	0.44
194	2330	7/26	46°25'N	132°31'W	59.4	240	28	62.1	62.1	1018	52	0	8	5	4	250	3	-	-
195	0230	7/27	46°16'N	132°04'W	58.3	250	20	60.4	60.4	1017	52	0	8	5	4	250	3	32.61	0.64
196	0455	7/27	46°06'N	131°43'W	58.3	250	20	60.2	60.2	1017	53	X	X	5	4	250	4	-	0.57
197	0630	7/27	46°06'N	131°43'W	58.3	250	20	60.2	60.6	1017	53	X	X	5	4	250	4	-	-
198	1400	7/27	46°10'N	131°19'W	58.8	300	16	61.0	61.0	1017	02	0	8	5	3	250	4	32.52	0.68
199	1640	7/27	46°09'N	130°51'W	59.2	250	14	60.0	60.0	1018	02	0	8	5	4	260	4	-	-
200	1830	7/27	46°08'N	130°30'W	59.0	250	16	61.8	60.5	1018	01	0	7	7	3	270	5	32.48	0.56
201	2100	7/27	46°06'N	130°04'W	59.5	220	16	63.0	61.0	1019	02	0, 5	1	7	3	230	3	32.57	0.69
202	2312	7/27	46°05'N	129°48'W	60.3	220	14	63.8	63.2	1019	03	X	8	7	3	230	3	32.61	0.56
203	0215	7/28	46°02'N	129°22'W	60.8	200	12	62.7	62.7	1018	02	0	8	7	3	230	3	32.54	0.50
204	0450	7/28	46°01'N	128°55'W	60.4	220	18	62.0	62.0	1019	45	0	8	5	3	250	3	32.52	0.68
205	0700	7/28	46°01'N	128°55'W	60.5	230	20	61.2	60.8	1018	45	X	X	5	3	XX	X	-	-
206	1400	7/28	46°02'N	128°39'W	60.3	220	19	62.1	61.2	1015	53	0	8	5	4	240	4	32.52	0.51
207	1630	7/28	46°01'N	128°14'W	60.4	230	16	62.0	60.8	1016	53	0	8	5	4	270	4	32.57	0.35
208	1830	7/28	46°01'N	127°54'W	61.0	200	18	63.0	63.0	1016	51	0	8	6	3	260	2	32.50	0.55
209	2105	7/28	45°58'N	127°29'W	61.5	230	17	65.8	64.0	1016	40	0	8	7	3	260	2	32.43	0.51

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
210	2335	7/28	45°45'N	127°19'W	62.5	240	11	63.2	63.2	1016	40	0	8	6	3	260	2	32.41	0.54
211	0200	7/29	45°29'N	127°06'W	62.5	330	12	64.0	64.0	1017	47	0	8	4	3	260	2	32.30	-
212	0435	7/29	45°15'N	126°53'W	63.2	330	10	62.0	62.0	1017	20	0	8	7	2	260	2	-	0.57
213	0540	7/29	45°15'N	126°53'W	63.2	330	10	62.0	62.0	1017	20	0	8	7	2	260	2	-	-
214	1400	7/29	45°00'N	126°32'W	62.5	350	09	61.0	59.5	1018	02	6,8	8	9	2	260	2	31.71	0.42
215	1630	7/29	44°46'N	126°19'W	64.1	010	14	63.0	61.6	1018	01	6,8	3	9	2	260	2	30.21	0.33
216	1830	7/29	44°34'N	126°08'W	64.6	350	15	63.4	62.0	1018	03	6,8	5	9	2	260	2	30.19	0.40
217	2105	7/29	44°20'N	125°54'W	64.4	320	11	64.3	61.8	1019	03	6,8	6	9	2	290	1	30.28	0.40
218	2335	7/29	44°13'N	125°47'W	64.4	340	15	64.3	60.3	1018	03	6	7	9	3	280	1	30.84	0.42
219	0200	7/30	44°05'N	125°27'W	61.6	330	14	63.8	60.2	1018	03	6,8	7	9	2	280	1	30.62	0.48
220	0420	7/30	44°00'N	125°07'W	60.8	330	17	62.6	61.0	1018	02	6,8	7	9	2	280	1	-	0.64
221	0525	7/30	44°00'N	125°07'W	60.0	330	17	62.6	62.0	1018	02	X	X	9	2	XX	X	-	-
222	0810	7/30	43°49'N	124°53'W	60.6	340	14	61.3	60.2	1018	02	X	X	9	2	XX	X	32.12	0.52
223	1400	7/30	43°43'N	124°58'W	60.9	010	10	63.4	61.8	1018	01	8	3	9	2	280	1	32.05	0.41
224	1640	7/30	43°34'N	125°20'W	61.0	350	08	66.2	63.9	1019	02	5,8	2	9	2	290	2	32.00	0.30
225	1805	7/30	43°29'N	125°33'W	59.3	350	08	67.1	63.8	1020	01	5,8	1	9	2	290	2	32.47	-
226	1825	7/30	43°27'N	125°38'W	60.0	350	08	67.1	63.8	1020	01	5,8	1	9	2	290	2	-	0.30
227	2100	7/30	43°18'N	126°00'W	62.4	350	08	65.4	62.7	1021	02	5,8	1	9	2	290	2	-	0.29
228	2330	7/30	43°12'N	126°16'W	64.3	330	12	65.1	62.5	1021	03	8	4	9	2	330	2	-	0.40
229	0210	7/31	43°05'N	126°37'W	64.2	340	09	64.0	61.2	1021	01	8	3	9	2	310	3	-	0.32
230	0435	7/31	42°56'N	126°59'W	64.0	330	14	62.9	60.7	1021	02	8	2	9	2	310	2	32.07	0.44
231	0625	7/31	42°56'N	126°59'W	64.0	330	10	62.9	60.7	1021	02	X	X	9	2	XX	X	32.07	-
232	1440	7/31	42°46'N	127°18'W	63.6	320	16	62.3	59.1	1022	03	8	6	9	2	310	1	-	-
233	1630	7/31	42°42'N	127°31'W	63.4	340	18	63.0	61.0	1023	02	8	6	9	2	340	1	32.19	0.50
234	1830	7/31	42°37'N	127°46'W	63.5	350	18	66.3	62.9	1024	02	4,8	6	9	2	340	1	32.14	0.41
235	2100	7/31	42°32'N	128°05'W	63.2	350	18	65.2	61.6	1024	01	4,8	7	9	2	340	1	32.16	0.56
236	2330	7/31	42°28'N	128°22'W	63.6	340	14	64.7	62.5	1025	03	4,8	2	9	2	340	1	32.42	0.48
237	0200	8/1	42°23'N	128°44'W	63.0	360	17	63.3	61.9	1025	02	8	5	9	2	350	1	32.78	0.58
238	0430	8/1	42°17'N	129°05'W	62.6	360	17	62.5	61.0	1026	02	8	5	9	2	350	1	32.86	0.69
239	0630	8/1	42°16'N	129°05'W	62.5	350	16	62.5	61.0	1026	02	X	X	9	2	XX	X	32.86	-
240	1400	8/1	42°07'N	129°17'W	62.2	010	15	61.2	60.0	1027	03	6,8	7	9	2	020	1	32.77	0.55
241	1630	8/1	42°00'N	129°37'W	62.7	340	14	63.1	61.8	1027	02	6,8	8	9	2	020	1	32.86	0.54
242	1830	8/1	41°55'N	129°53'W	62.7	350	15	63.8	61.8	1027	02	6,8	6	9	2	020	1	32.91	0.45
243	2105	8/1	41°48'N	130°13'W	63.3	350	18	65.7	63.0	1028	01	8	2	9	2	010	1	32.86	0.57
244	2340	8/1	41°44'N	130°28'W	63.4	360	13	64.8	60.2	1027	02	8	2	9	2	010	1	32.88	0.52

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
245	0200	8/2	41°38'N	130°47'W	63.6	340	14	63.6	60.8	1027	02	8	4	9	2	010	1	32.94	0.48
246	0435	8/2	41°33'N	131°06'W	63.2	330	10	62.8	60.2	1027	02	8	5	9	2	010	1	32.74	-
247	0600	8/2	41°33'N	131°06'W	63.0	340	11	62.8	60.2	1028	02	X	X	9	2	XX	1	32.74	0.57
248	0805	8/2	41°33'N	130°47'W	62.9	330	13	61.2	59.2	1027	02	X	X	9	2	XX	X	32.86	0.42
249	1400	8/2	41°31'N	130°34'W	62.5	000	09	61.8	60.4	1025	02	8	2	9	2	010	2	32.93	0.51
250	1635	8/2	41°29'N	130°09'W	62.6	330	11	62.2	60.3	1025	03	8	3	9	2	360	1	32.88	0.63
251	1840	8/2	41°28'N	129°49'W	62.8	320	10	63.3	60.8	1025	02	8	3	9	1	020	1	32.86	0.49
252	2100	8/2	41°26'N	129°26'W	63.3	330	07	63.0	61.2	1024	02	1,8	2	9	1	020	1	32.93	0.44
253	2330	8/2	41°24'N	129°09'W	63.8	280	14	63.9	61.0	1017	03	1,8	3	9	1	010	1	32.84	0.49
254	0205	8/3	41°21'N	128°48'W	63.3	270	16	63.6	62.1	1022	03	0	8	9	1	010	1	32.90	0.46
255	0425	8/3	41°18'N	128°25'W	63.0	280	12	63.0	61.9	1021	02	0	8	9	1	340	1	32.86	0.55
256	0530	8/3	41°18'N	128°25'W	62.8	270	12	62.8	61.3	1021	02	X	X	9	2	300	1	32.86	-
257	1400	8/3	41°14'N	127°53'W	62.7	240	13	66.3	66.3	1015	55	X	X	5	2	240	2	32.85	0.49
258	1630	8/3	41°11'N	127°31'W	62.7	290	16	64.3	62.9	1016	01	1,8	6	9	2	260	2	32.75	0.51
259	1830	8/3	41°08'N	127°13'W	62.6	290	19	64.0	62.1	1016	01	0,8	6	9	3	260	2	32.53	0.40
260	2044	8/3	41°03'N	126°52'W	59.6	290	15	64.5	63.8	1015	02	0,8	6	9	2	260	2	32.60	0.52
261	2120	8/3	41°04'N	126°56'W	61.8	280	12	65.2	63.7	1015	02	0,8	6	9	2	260	2	32.76	0.68
262	0040	8/4	41°02'N	126°41'W	60.0	240	10	63.5	62.9	1015	02	0,8	6	9	3	280	2	32.79	-
263	0145	8/4	41°02'N	126°39'W	61.0	280	09	65.7	64.3	1014	02	0,8	6	9	3	280	2	32.79	0.57
264	0530	8/4	40°58'N	126°01'W	60.3	240	10	64.9	63.3	1014	01	0,8	4	9	2	XX	X	-	0.51
265	1415	8/4	40°47'N	125°33'W	60.3	220	10	62.0	59.1	1013	01	4	1	9	2	280	2	32.12	0.54
266	1506	8/4	40°47'N	125°24'W	57.7	220	10	60.6	58.2	1014	00	4	1	9	2	280	2	32.62	0.63
267	1620	8/4	40°48'N	125°15'W	54.9	180	12	58.8	56.3	1014	03	4	6	9	2	280	2	-	1.32
268	1735	8/4	40°48'N	125°02'W	54.1	160	13	60.8	57.3	1014	02	4,8	6	9	2	290	2	33.04	0.86
269	1835	8/4	40°48'N	125°01'W	54.2	160	11	60.8	57.3	1014	02	4,8	6	9	2	290	2	33.04	-
270	2105	8/4	40°41'N	125°16'W	54.7	190	13	61.1	57.5	1015	18	8	8	9	2	290	4	32.90	0.70
271	2220	8/4	40°38'N	125°25'W	56.3	200	13	59.9	58.7	1015	18	5,8	6	9	3	270	4	32.84	0.70
272	2350	8/4	40°35'N	125°34'W	60.4	200	13	61.4	59.8	1014	01	5,8	2	9	3	270	4	-	-
273	0210	8/5	40°31'N	125°51'W	60.3	230	12	60.3	59.8	1014	02	5,8	3	9	3	270	4	32.68	0.55
274	0545	8/5	40°26'N	126°16'W	59.7	220	12	61.3	60.1	1015	00	X	X	9	3	XX	X	32.64	0.63
275	1410	8/5	40°23'N	126°30'W	57.6	310	08	64.2	63.0	1015	02	5,8	7	9	3	270	4	32.64	-
276	1645	8/5	40°18'N	126°54'W	59.3	300	11	60.9	59.6	1017	01	0,5,8	5	9	2	290	3	33.03	0.67
277	1745	8/5	40°18'N	126°54'W	59.6	300	13	60.9	59.6	1017	01	0,5,8	5	9	2	290	3	33.03	-
278	1920	8/5	40°15'N	127°09'W	58.3	280	11	63.7	61.0	1017	02	0,5,8	6	9	3	320	3	32.94	0.39
279	2100	8/5	40°12'N	127°23'W	62.4	290	15	66.5	62.1	1018	03	5,8	6	9	3	280	3	32.68	0.49

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
280	2330	8/5	40°07'N	127°38'W	63.1	310	15	64.9	60.9	1018	03	4,5,8	7	9	4	290	3	32.66	0.34
281	0210	8/6	40°03'N	127°57'W	62.7	300	18	63.5	60.7	1019	03	6	8	9	4	290	3	32.74	0.42
282	0425	8/6	40°01'N	128°16'W	63.0	320	14	62.3	59.2	1019	02	5,6	8	9	4	290	3	32.84	-
283	0925	8/6	40°16'N	128°32'W	63.0	080	15	63.7	60.7	1019	00	X	X	9	3	XX	X	32.84	-
284	1310	8/6	39°55'N	128°34'W	63.3	240	10	62.4	60.7	1018	50	0	8	8	2	280	4	32.83	-
285	1600	8/6	39°51'N	128°57'W	63.1	270	06	63.8	62.7	1019	01	0,5,6,8	7	9	2	310	4	32.84	0.56
286	1705	8/6	39°51'N	128°57'W	63.2	270	06	63.8	62.7	1019	01	0,5,6,8	7	9	2	310	4	32.84	-
287	1900	8/6	39°48'N	129°13'W	63.5	270	10	64.2	62.9	1019	15	0,8	7	6	3	280	1	32.83	0.59
288	2100	8/6	39°45'N	129°29'W	63.5	300	11	66.6	63.2	1019	15	0,8	7	6	3	280	1	32.87	0.55
289	2330	8/6	39°41'N	129°47'W	63.8	300	15	67.8	63.4	1019	02	0,8	7	6	3	280	1	32.92	0.55
290	0200	8/7	39°37'N	130°10'W	63.6	300	13	65.0	61.6	1019	02	6	8	9	3	310	1	32.91	0.56
291	0430	8/7	39°33'N	130°33'W	64.4	300	15	65.0	63.4	1019	XX	X	X	8	3	XX	X	32.98	0.58
292	0725	8/7	39°30'N	131°01'W	64.6	300	15	64.2	61.4	1020	XX	X	X	8	3	XX	X	32.93	0.52
293	1210	8/7	39°29'N	130°58'W	63.9	300	14	62.6	60.2	1019	00	X	X	7	3	XX	X	32.95	0.45
294	1310	8/7	39°29'N	130°58'W	63.8	300	14	62.6	60.2	1019	00	X	X	7	3	XX	X	32.95	-
295	1600	8/7	39°25'N	130°31'W	63.6	300	15	64.6	63.3	1020	02	0,8	8	8	3	330	2	32.93	0.61
296	1830	8/7	39°21'N	130°08'W	63.9	300	11	65.8	62.7	1020	02	0,8	8	8	3	330	2	33.00	0.55
297	2105	8/7	39°17'N	129°45'W	64.0	180	04	69.4	67.2	1020	18	0,8	8	8	3	330	2	33.00	-
298	2330	8/7	39°14'N	129°26'W	64.0	350	04	67.1	64.2	1020	01	2,8	5	9	2	290	1	32.95	0.55
299	0205	8/8	39°11'N	129°04'W	64.2	340	12	68.8	65.3	1019	01	2,8	6	9	2	290	1	32.99	0.59
300	0425	8/8	39°08'N	128°40'W	63.9	310	14	64.3	62.5	1020	00	X	X	9	2	290	1	32.92	0.57
301	0520	8/8	39°08'N	128°40'W	63.9	310	14	64.3	62.5	1020	00	X	X	9	2	290	1	32.92	-
302	1400	8/8	39°02'N	128°21'W	63.5	350	13	63.6	61.4	1021	03	2,8	7	9	2	330	1	32.95	0.59
303	1645	8/8	39°00'N	128°01'W	63.6	010	13	63.2	61.3	1022	51	0,6,8	7	9	2	340	2	32.96	0.56
304	1830	8/8	38°59'N	127°55'W	63.7	330	10	63.7	62.0	1022	02	6,8	7	9	2	320	1	33.02	0.56
305	2112	8/8	39°00'N	127°36'W	63.8	330	08	67.8	64.3	1022	02	4,6,8	7	9	2	320	1	32.93	0.56
306	2230	8/8	39°00'N	127°33'W	64.2	310	06	67.0	59.3	1021	01	5,8	6	9	2	270	2	32.99	NS
307	2330	8/8	39°00'N	127°33'W	64.0	310	06	67.0	59.3	1021	01	5,8	6	9	2	270	2	32.99	-
308	0200	8/9	39°03'N	127°17'W	63.7	000	00	63.9	59.6	1020	01	5,8	2	9	1	270	1	32.88	0.56
309	0425	8/9	39°03'N	127°01'W	61.2	330	09	63.0	59.2	1021	02	5,6	1	9	1	270	1	32.86	0.61
310	1400	8/9	39°08'N	126°39'W	62.9	270	06	64.7	60.8	1019	02	6	8	9	1	290	2	32.88	0.50
311	1630	8/9	39°09'N	126°15'W	62.9	250	04	65.0	61.0	1019	02	0	9	9	1	320	2	32.88	0.60
312	1830	8/9	39°10'N	125°56'W	62.7	360	13	61.5	59.9	1019	28	0	8	9	2	320	2	32.86	0.60
313	2030	8/9	39°11'N	125°37'W	63.0	320	08	64.0	60.0	1019	01	0,6	6	9	2	340	1	32.88	0.56
314	2130	8/9	39°11'N	125°37'W	63.1	320	08	64.0	60.0	1019	01	0,6	6	9	2	340	1	32.88	-

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
315	2300	8/9	39°09'N	125°26'W	62.8	310	15	64.2	62.2	1022	01	0,6	2	9	2	340	1	32.89	0.55
316	0130	8/10	39°05'N	125°02'W	62.5	360	15	63.1	59.9	1017	01	8	1	9	2	300	1	32.87	0.54
317	0353	8/10	39°01'N	124°37'W	58.0	330	17	61.0	58.5	1017	02	8	1	9	3	310	1	32.81	0.60
318	1205	8/10	38°54'N	124°21'W	56.1	330	18	58.9	57.1	1015	02	8	1	9	3	330	2	33.17	1.17
319	1305	8/10	38°54'N	124°21'W	56.2	330	20	58.9	57.1	1015	02	8	1	9	3	330	2	33.17	-
320	1630	8/10	38°44'N	124°44'W	57.5	320	18	63.3	59.8	1016	02	8	1	9	3	330	2	33.38	1.10
321	1830	8/10	38°39'N	124°55'W	57.6	310	16	64.8	60.2	1017	02	8	1	9	3	330	2	33.30	1.19
322	2000	8/10	38°36'N	125°03'W	60.9	320	18	65.1	60.3	1017	02	8	1	9	3	300	2	33.03	0.94
323	2200	8/10	38°33'N	125°19'W	63.0	320	22	66.7	61.2	1018	02	8	1	9	3	320	2	32.87	0.71
324	2335	8/10	38°31'N	125°31'W	62.6	340	20	64.1	59.9	1017	03	8	6	9	3	320	2	32.85	0.56
325	0215	8/11	38°28'N	125°48'W	62.7	340	18	64.3	61.2	1017	01	8	2	9	3	320	2	32.95	0.63
326	0410	8/11	38°26'N	126°04'W	62.8	330	22	62.8	59.2	1018	01	8	2	9	3	XX	X	32.86	0.56
327	0515	8/11	38°26'N	126°04'W	62.7	330	22	62.8	59.2	1018	01	8	2	9	3	XX	X	32.86	-
328	1000	8/11	38°40'N	126°33'W	62.6	330	20	63.5	59.6	1017	02	8	3	9	3	XX	X	32.90	0.54
329	1245	8/11	38°26'N	126°47'W	61.2	020	16	63.8	60.3	1017	02	8	4	9	3	XX	X	32.93	0.69
330	1430	8/11	38°19'N	127°01'W	60.2	340	09	63.8	60.4	1018	02	8	3	9	3	320	2	32.99	0.63
331	1630	8/11	38°13'N	127°16'W	63.2	330	15	65.3	60.8	1019	03	0,6,8	6	9	2	360	1	32.88	0.58
332	1740	8/11	38°11'N	127°24'W	63.8	360	12	65.3	61.7	1019	02	0,6,8	6	9	2	360	1	32.95	0.58
333	2100	8/11	38°03'N	127°50'W	63.7	330	14	64.7	60.8	1021	01	6,2,8	2	9	2	320	1	33.04	0.50
334	2200	8/11	38°03'N	127°51'W	63.8	330	14	64.7	60.8	1021	01	6,2,8	2	9	2	320	1	33.04	-
335	0030	8/12	37°59'N	128°08'W	64.4	330	13	66.7	61.5	1017	02	8	2	9	2	300	2	32.94	0.44
336	0315	8/12	37°54'N	128°29'W	63.9	340	16	64.9	60.7	1021	01	8	1	9	2	340	1	32.94	0.47
337	0600	8/12	37°48'N	128°55'W	64.1	330	15	63.8	59.8	1022	02	8	2	9	2	310	1	32.97	0.46
338	0800	8/12	37°42'N	129°17'W	65.5	330	13	64.2	60.0	1023	01	8	1	9	2	310	1	33.03	0.39
339	1005	8/12	37°37'N	129°39'W	65.5	320	17	65.5	61.5	1022	00	X	X	8	2	XX	X	33.08	0.52
340	1205	8/12	37°31'N	130°01'W	65.4	340	15	65.3	61.1	1023	02	6,8	8	8	2	XX	X	33.06	0.50
341	1300	8/12	37°29'N	130°12'W	65.3	320	11	64.7	59.2	1023	02	6	8	9	2	XX	X	33.06	NS
342	1355	8/12	37°29'N	130°12'W	65.3	320	11	64.7	59.2	1023	02	6	8	9	2	XX	X	33.06	-
343	1630	8/12	37°26'N	129°55'W	65.6	360	15	64.4	58.8	1025	02	6	8	9	2	360	1	33.22	0.45
344	1830	8/12	37°22'N	129°37'W	65.1	360	13	65.0	59.9	1024	02	6	8	9	2	360	1	33.33	0.57
345	2100	8/12	37°19'N	129°20'W	65.6	360	16	65.4	60.6	1024	02	6	8	9	2	360	1	33.19	0.44
346	2310	8/12	37°16'N	129°08'W	64.3	350	14	66.4	62.0	1023	02	6	8	9	2	360	1	33.10	0.44
347	0230	8/13	37°11'N	128°46'W	64.2	350	15	64.0	61.0	1023	02	6	8	9	3	360	1	33.04	0.44
348	0405	8/13	37°09'N	128°35'W	64.3	360	15	64.3	60.0	1023	02	6	8	9	3	XX	X	33.10	0.50
349	0505	8/13	37°09'N	128°35'W	64.2	360	15	64.3	60.0	1023	02	6	8	9	3	XX	X	33.10	-

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
350	1400	8/13	37°02'N	128°23'W	64.1	010	12	63.9	60.0	1023	02	6	8	9	3	010	1	32.99	-
351	1635	8/13	37°02'N	128°04'W	64.3	020	26	64.2	60.4	1023	02	8	8	9	2	360	2	33.03	0.32
352	1835	8/13	37°02'N	127°39'W	63.8	020	29	64.4	60.4	1023	02	8	8	9	3	360	2	33.01	0.33
353	2100	8/13	37°01'N	127°30'W	63.5	020	19	64.6	60.3	1022	01	8	7	9	3	360	3	32.95	0.31
354	2345	8/13	36°58'N	127°11'W	63.4	350	21	63.7	60.3	1021	01	8	4	9	3	360	3	32.94	0.30
355	0207	8/14	36°54'N	126°51'W	63.4	350	21	63.3	61.3	1020	01	8	2	9	3	360	3	32.92	0.44
356	0400	8/14	36°52'N	126°35'W	63.4	330	20	63.0	60.9	1020	02	8	2	9	3	360	3	32.95	0.57
357	0500	8/14	36°52'N	126°35'W	63.3	330	20	63.0	60.9	1020	02	8	2	9	3	360	3	32.95	-
358	1405	8/14	36°48'N	126°21'W	62.7	350	18	62.8	58.0	1019	02	8	7	9	3	360	3	32.92	0.33
359	1630	8/14	36°52'N	126°01'W	62.8	350	21	62.5	57.1	1019	02	6	6	9	3	360	3	32.92	-
360	1905	8/14	36°57'N	125°40'W	62.6	330	19	63.1	59.6	1019	02	6	6	9	3	010	3	32.90	0.33
361	2100	8/14	37°01'N	125°26'W	63.1	340	16	63.0	59.8	1018	02	4	6	9	3	350	3	32.94	-
362	2300	8/14	37°03'N	125°14'W	61.3	340	16	62.7	59.6	1018	01	8	1	9	3	350	3	32.97	0.41
363	0210	8/15	37°08'N	124°54'W	60.0	330	15	62.1	59.9	1017	02	8	1	9	3	350	3	33.04	0.50
364	0400	8/15	37°12'N	124°41'W	60.3	320	17	61.1	59.2	1017	02	8	1	9	3	350	3	33.21	-
365	0550	8/15	37°12'N	124°41'W	59.8	320	17	61.1	59.2	1017	02	8	1	9	3	XX	X	33.21	0.57
366	0800	8/15	37°19'N	124°16'W	59.5	320	21	61.1	58.8	1016	02	8	1	9	3	XX	X	33.22	0.59
367	1000	8/15	37°26'N	123°53'W	57.3	270	24	60.2	58.2	1016	00	X	X	9	2	XX	X	33.58	0.69
368	1205	8/15	37°31'N	123°32'W	57.9	320	23	58.3	56.4	1016	00	X	X	9	3	XX	X	33.66	0.63
369	1305	8/15	37°31'N	123°32'W	58.0	320	23	58.3	56.4	1016	00	X	X	9	3	XX	X	33.66	-
370	0005	8/27	37°24'N	122°35'W	56.5	160	01	59.8	56.6	1020	03	8	7	9	1	080	1	32.70	1.43
371	0530	8/27	36°44'N	122°25'W	59.4	320	15	58.1	56.3	1020	00	X	X	8	1	XX	X	-	-
372	0740	8/27	36°25'N	122°20'W	56.2	320	12	60.8	57.5	1020	00	X	X	8	1	XX	X	33.40	0.89
373	0930	8/27	36°04'N	122°16'W	58.0	320	18	60.5	57.7	1020	00	X	X	8	2	XX	X	-	-
374	1200	8/27	35°39'N	122°13'W	56.5	320	18	59.8	57.0	1020	00	X	X	8	3	XX	X	33.60	1.12
375	1258	8/27	35°39'N	122°13'W	56.2	320	18	59.7	56.9	1020	00	1, 3	2	8	3	340	1	33.60	-
376	1530	8/27	35°32'N	122°33'W	57.5	340	26	61.0	57.8	1020	03	1, 3	3	9	3	340	1	33.42	0.88
377	1800	8/27	35°25'N	122°51'W	58.2	350	24	61.5	58.2	1022	03	4	6	8	3	340	1	33.44	0.75
378	2100	8/27	35°14'N	123°13'W	60.0	360	23	64.3	60.3	1022	01	4	3	9	3	340	1	33.55	0.62
379	2330	8/27	35°01'N	123°28'W	62.5	360	22	64.8	60.6	1021	01	4	1	9	3	340	1	33.48	0.68
380	0205	8/28	34°48'N	123°43'W	62.2	330	21	63.8	60.1	1020	01	4	1	9	3	340	1	33.51	0.63
381	0430	8/28	34°34'N	124°05'W	63.0	330	21	63.0	59.2	1021	00	X	X	8	3	340	1	33.31	0.74
382	0630	8/28	34°25'N	124°26'W	63.9	340	20	63.8	59.7	1021	00	X	X	8	3	XX	X	33.15	0.69
383	0835	8/28	34°16'N	124°48'W	64.1	320	18	64.8	60.4	1021	00	X	X	8	3	XX	X	33.12	0.63
384	1035	8/28	34°06'N	125°10'W	63.7	320	20	62.8	59.8	1020	00	X	X	8	3	XX	X	33.13	0.77

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
385	1258	8/28	33°54'N	125°36'W	64.0	320	20	64.0	58.8	1021	00	X	X	8	3	XX	X	33.24	0.58
386	1356	8/28	33°54'N	125°36'W	63.9	320	19	63.0	58.0	1021	03	6,8	3	8	3	320	2	33.24	-
387	1630	8/28	33°48'N	125°56'W	65.0	320	18	66.7	59.8	1021	02	6,8	2	9	3	320	2	33.28	0.84
388	1900	8/28	33°42'N	126°15'W	66.1	320	16	68.3	61.8	1021	02	6,8	2	9	2	320	2	33.37	0.69
389	2100	8/28	33°37'N	126°30'W	66.0	350	13	66.9	60.9	1021	02	8	3	9	2	320	2	33.37	-
390	0035	8/29	33°24'N	127°06'W	66.8	310	14	68.7	62.7	1020	02	8	4	9	2	320	2	33.37	0.57
391	0356	8/29	33°08'N	127°47'W	66.3	330	08	66.2	61.5	1020	02	6,8	4	9	2	320	2	33.22	0.47
392	0458	8/29	33°08'N	127°47'W	66.3	330	08	66.1	61.3	1020	00	X	X	9	2	320	2	33.22	-
393	0900	8/29	32°55'N	128°25'W	66.5	290	08	68.2	63.2	1020	00	X	X	9	2	XX	X	-	-
394	1300	8/29	32°38'N	129°10'W	67.2	310	07	66.0	61.2	1019	00	X	X	9	1	XX	X	33.39	-
395	1600	8/29	32°26'N	129°43'W	68.3	340	05	67.8	62.1	1020	02	6,8	1	9	1	010	1	33.64	-
396	1657	8/29	32°26'N	129°43'W	68.3	340	05	69.0	63.0	1020	03	6,8	2	9	1	010	1	33.64	-
397	2100	8/29	32°10'N	130°28'W	70.0	320	07	73.4	65.4	1020	03	6,8	4	9	1	010	1	34.04	-
398	0100	8/30	31°55'N	131°11'W	71.0	320	04	71.5	64.0	1019	02	6,8	2	9	1	010	1	34.04	-
399	0353	8/30	31°43'N	131°44'W	71.1	270	04	70.3	63.5	1019	02	6	3	9	1	010	1	34.09	-
400	0445	8/30	31°43'N	131°44'W	71.1	270	05	70.5	64.0	1020	00	X	X	9	1	010	1	34.09	-
401	0900	8/30	31°29'N	132°22'W	69.4	270	05	71.3	65.0	1020	00	X	X	8	1	XX	X	33.98	-
402	1300	8/30	31°13'N	133°03'W	70.4	270	14	72.0	67.4	1019	00	X	X	8	1	XX	X	33.93	-
403	1555	8/30	31°01'N	133°36'W	70.2	270	08	71.0	67.2	1021	03	1,4,8	2	9	1	XX	1	34.27	-
404	1655	8/30	31°01'N	133°36'W	70.2	270	08	72.0	67.6	1021	02	1,4,8	4	9	1	XX	1	34.27	-
405	2100	8/30	30°44'N	134°20'W	70.5	280	12	73.0	69.0	1021	03	4,1,8	3	9	2	XX	1	34.31	-
406	0100	8/31	30°27'N	135°01'W	71.1	280	12	74.3	69.0	1021	02	4,8	6	9	2	320	1	34.11	-
407	0357	8/31	30°14'N	135°33'W	71.4	280	09	72.9	68.1	1021	02	4,8	2	9	1	320	1	34.25	-
408	0450	8/31	30°14'N	135°33'W	71.4	280	09	72.5	68.0	1021	00	X	X	9	1	320	1	34.25	-
409	0850	8/31	30°03'N	136°05'W	70.5	260	10	72.8	68.8	1022	00	X	X	9	1	XX	X	34.31	-
410	1300	8/31	29°46'N	136°54'W	71.2	300	11	71.1	67.0	1022	00	X	X	9	1	XX	X	34.88	-
411	1655	8/31	29°29'N	137°39'W	72.3	280	09	72.5	69.4	1023	03	1,4,8	5	9	1	300	2	35.25	-
412	1749	8/31	29°29'N	137°39'W	72.3	280	08	72.9	68.4	1023	02	4,6,8	5	9	1	300	2	35.25	-
413	2200	8/31	29°12'N	138°23'W	73.5	300	12	76.8	70.4	1023	02	4,6,8	6	9	1	300	2	35.35	-
414	0200	9/1	28°57'N	139°03'W	73.2	330	07	73.8	69.2	1023	50	4,6,8	7	9	1	300	2	35.41	-
415	0450	9/1	28°45'N	139°36'W	73.2	330	05	73.6	69.8	1023	21	X	7	6	2	XX	2	35.43	-
416	0545	9/1	28°45'N	139°36'W	73.3	330	07	73.7	69.0	1024	21	X	8	6	1	XX	2	35.43	-
417	1000	9/1	28°29'N	140°14'W	73.3	350	06	74.0	69.8	1023	00	X	X	9	1	XX	2	35.34	-
418	1305	9/1	28°17'N	140°47'W	73.7	350	06	73.4	69.4	1022	00	X	X	8	1	XX	2	35.32	-
419	1655	9/1	28°01'N	141°30'W	73.1	030	08	74.8	69.8	1023	03	1,8	2	9	1	070	1	35.37	-

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 40 (NEPAS)(for coded values see H. O. Pub. 606-c)(cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
420	1755	9/1	28°01'N	141°30'W	73.2	030	07	74.9	69.1	1023	03	5,8	4	9	1	070	1	35.37	-
421	2200	9/1	27°43'N	142°13'W	74.5	050	10	72.2	69.9	1023	02	6	2	9	1	120	1	35.41	-
422	0100	9/2	27°32'N	142°43'W	74.1	050	10	76.8	70.0	1021	02	5,6	4	9	1	130	1	35.37	-
423	0450	9/2	27°16'N	143°27'W	74.1	050	10	76.2	70.0	1022	02	6	2	9	1	130	1	35.32	-
424	0547	9/2	27°16'N	143°27'W	74.1	050	10	74.0	69.9	1022	00	X	X	9	1	130	1	35.32	-
425	1000	9/2	27°00'N	144°06'W	73.7	100	08	74.8	70.7	1022	00	X	X	8	1	XX	X	35.41	-
426	1245	9/2	26°46'N	144°38'W	73.7	100	08	73.8	68.4	1021	00	X	X	9	1	XX	X	35.41	-
427	1655	9/2	26°28'N	145°20'W	73.4	050	05	71.8	68.4	1022	21	0,8	8	6	1	100	1	35.46	-
428	1752	9/2	26°28'N	145°20'W	73.4	050	05	74.0	69.3	1022	01	0,8	6	8	1	100	1	35.46	-
429	2200	9/2	26°10'N	146°01'W	75.3	090	13	76.3	70.4	1021	01	0,8	4	9	2	100	1	35.26	-
430	0100	9/3	25°59'N	146°28'W	75.4	250	10	75.0	69.3	1019	02	0,8	5	9	2	100	1	35.26	-
431	0450	9/3	25°41'N	147°10'W	74.3	070	10	75.9	70.9	1019	02	1,6,8,3	7	9	2	100	1	35.30	-
432	1000	9/3	25°25'N	147°48'W	75.0	140	08	73.6	69.9	1020	50	X	8	9	2	100	1	35.41	-
433	1300	9/3	25°12'N	148°20'W	75.3	100	13	74.4	70.8	1019	00	X	X	8	2	XX	X	35.37	-
434	1655	9/3	24°55'N	149°00'W	75.6	100	15	75.6	71.5	1019	02	4,6,8	6	9	2	070	2	35.26	-
435	1802	9/3	24°55'N	149°00'W	75.5	100	18	73.8	71.3	1019	03	1,6	6	9	2	070	2	35.26	-
436	2200	9/3	24°38'N	149°40'W	75.4	140	05	75.2	71.6	1019	16	0,1,8	7	6	2	130	2	35.39	-
437	0100	9/4	24°25'N	150°09'W	76.6	070	09	77.5	71.9	1018	15	1,5,7,6	7	7	2	130	2	35.39	-
438	0550	9/4	24°07'N	150°51'W	76.0	100	07	75.5	71.6	1019	00	X	6	9	2	130	2	35.25	-
439	0645	9/4	24°07'N	150°51'W	76.1	100	08	75.2	71.3	1019	00	X	X	9	2	130	2	35.25	-
440	1100	9/4	23°52'N	151°28'W	75.9	100	13	72.7	71.0	1018	00	X	X	9	2	XX	X	35.35	-
441	1400	9/4	23°39'N	151°59'W	76.4	070	07	75.6	71.7	1017	00	X	X	9	2	XX	X	-	-
442	1753	9/4	23°21'N	152°41'W	76.7	070	14	76.5	73.0	1018	15	6,8,1	6	8	3	070	1	34.92	-
443	1900	9/4	23°21'N	152°41'W	76.7	070	12	76.5	72.8	1018	15	1,6,8	6	8	3	070	1	34.92	-
444	2300	9/4	23°04'N	153°24'W	76.8	040	07	77.0	73.3	1017	50	1,6,8	8	8	2	070	1	35.19	-
445	0200	9/5	22°51'N	153°54'W	77.2	050	11	79.8	78.8	1015	01	1,6,8	5	8	2	070	1	35.17	-
446	0550	9/5	22°32'N	154°39'W	76.8	060	06	77.9	72.4	1017	02	X	7	9	2	060	1	35.17	-
447	0645	9/5	22°32'N	154°39'W	76.7	060	15	77.4	70.9	1017	01	X	2	9	2	060	1	35.17	-
448	1100	9/5	22°15'N	155°17'W	76.9	090	15	76.4	72.4	1016	50	X	2	7	2	XX	X	35.19	-
449	1500	9/5	21°58'N	155°58'W	77.3	090	16	76.4	70.8	1015	00	X	X	7	2	XX	X	34.99	
449A	1755	9/5	21°45'N	156°30'W	76.8	090	18	77.8	72.9	1016	03	1,8	8	9	3	090	1	34.94	-
450	1900	9/5	21°45'N	156°30'W	76.7	090	16	76.6	72.2	1016	02	1,8	8	9	3	090	1	34.94	-

Table 4.--Summary of observations at bathythermograph lowerings, John R. Manning cruise 36 (NEPAS) (for coded values see H. O. Pub. 606-c)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
1	1730	6/12	22°13'N	156°37'W	76.5	080	17	77.0	70.2	1020	02	6	6	8	4	090	4	-	-
2	2330	6/12	22°41'N	156°09'W	76.5	090	20	80.0	72.0	1020	02	6	3	8	4	090	4	-	-
3	0530	6/13	23°14'N	155°48'W	76.5	090	18	78.0	72.0	1020	02	6	1	9	3	090	4	35.19	-
4	1130	6/13	23°45'N	155°17'W	76.0	090	16	76.7	72.0	1021	00	6	8	7	3	090	4	-	-
5	1730	6/13	24°17'N	154°45'W	76.0	100	20	76.3	72.0	1022	03	6	7	7	4	100	4	-	-
6	2330	6/13	24°49'N	154°13'W	76.5	090	19	79.0	74.0	1022	02	4, 5, 6	7	8	4	090	4	35.34	-
7	0530	6/14	25°19'N	153°41'W	76.0	080	19	76.0	71.5	1022	01	6, 8	5	8	4	090	4	35.34	-
8	1130	6/14	25°51'N	153°08'W	75.5	080	15	75.1	70.0	1022	01	1, 4, 6	4	8	4	090	4	-	-
9	1730	6/14	26°24'N	152°36'W	75.0	080	16	76.5	71.0	1020	03	1, 6, 8	5	8	3	110	4	35.48	-
10	2330	6/14	26°54'N	152°09'W	75.5	090	12	76.5	71.0	1022	01	1, 6, 8	2	9	3	110	1	-	-
11	0530	6/15	27°26'N	151°36'W	75.5	090	15	75.5	70.0	1022	03	1, 6, 8	7	9	4	110	4	35.57	-
12	1130	6/15	27°55'N	151°01'W	75.2	070	11	74.0	70.0	1021	02	8	2	7	2	070	1	-	-
13	1730	6/15	28°31'N	150°25'W	75.0	090	14	76.0	70.5	1021	02	1, 4, 6, 8	3	9	2	090	1	35.68	-
14	0005	6/16	29°11'N	149°53'W	76.0	090	15	79.0	69.0	1021	01	1, 6, 8	3	9	4	090	1	-	-
15	0530	6/16	29°41'N	149°15'W	74.0	090	12	74.5	68.0	1020	02	1, 6, 8	3	9	3	090	4	35.34	0.37
16	1130	6/16	30°17'N	148°41'W	73.2	090	04	72.0	66.0	1020	02	8	6	7	2	090	1	-	-
17	1730	6/16	30°53'N	148°01'W	73.2	090	04	73.8	67.0	1020	02	6, 2, 4	1	9	2	090	1	35.19	0.22
18	2330	6/16	31°27'N	147°21'W	74.5	070	07	75.0	68.0	1022	02	5, 1	3	9	3	130	1	-	-
19	0530	6/17	31°58'N	146°40'W	73.8	080	10	74.0	68.0	1023	03	4, 5	4	9	2	090	1	34.88	0.25
20	1130	6/17	32°34'N	146°10'W	70.4	130	04	71.0	68.2	1024	02	5	8	6	2	060	1	-	-
21	1730	6/17	33°13'N	145°38'W	69.3	080	05	71.8	69.5	1026	03	1, 4	8	7	1	160	1	34.36	0.97
22	2330	6/17	33°51'N	145°02'W	73.0	140	02	73.0	67.1	1023	02	8, 5, 2	1	9	2	000	1	-	-
23	0530	6/18	34°21'N	144°25'W	70.3	160	02	72.0	67.0	1026	02	8, 5, 2	2	9	2	XX	1	34.22	0.32
24	1130	6/18	35°02'N	143°51'W	69.8	230	05	69.8	67.1	1026	02	8	2	8	2	XX	1	-	-
25	1730	6/18	35°43'N	143°17'W	67.0	230	11	67.1	66.2	1023	02	1, 8	5	8	2	300	1	34.29	0.21
26	2330	6/18	36°01'N	143°00'W	66.3	230	12	69.3	67.0	1024	02	6, 5	8	9	2	240	1	-	-
27	0530	6/19	36°10'N	142°52'W	65.5	250	13	66.6	64.5	1023	02	6	8	7	3	250	2	33.95	0.30
28	1630	6/19	36°14'N	142°45'W	65.5	310	15	66.0	64.0	1024	02	0, 6	9	7	4	300	1	34.02	-
29	2330	6/19	36°42'N	141°57'W	63.9	160	12	60.0	59.0	1025	02	6	7	9	5	160	5	-	0.43
30	0530	6/20	36°50'N	141°44'W	63.6	360	16	62.5	63.6	1023	02	0	8	8	2	350	1	33.82	0.46
31	1615	6/20	36°45'N	141°45'W	62.9	070	06	60.6	54.0	1027	02	6	5	8	2	090	X	-	0.32
32	2330	6/20	37°22'N	140°59'W	63.8	040	12	60.0	56.0	1026	02	6	X	8	2	020	1	33.69	-
33	0530	6/21	37°58'N	140°16'W	63.0	040	04	62.0	55.5	1026	02	6	8	7	3	020	1	33.68	1.30
34	1130	6/21	38°25'N	139°44'W	62.0	050	12	59.9	53.7	1026	02	6	8	6	3	050	2	-	-
35	1730	6/21	38°52'N	139°12'W	62.0	000	00	60.0	54.0	1026	02	6	8	7	2	010	1	33.51	-

Table 4.--Summary of observations at bathythermograph lowerings, John R. Manning cruise 36 (NEPAS) (for coded values see H. O. Pub. 606-c) (cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
36	2330	6/21	39°19'N	138°39'W	61.5	160	11	62.5	57.5	1025	02	6	8	7	2	350	1	-	-
37	0530	6/22	39°44'N	138°10'W	61.8	190	13	61.1	56.2	1023	02	6	6	7	2	190	2	33.48	0.31
38	1600	6/22	39°43'N	138°02'W	61.5	240	10	63.0	58.5	1022	02	6	8	7	3	250	1	-	0.42
39	2330	6/22	40°24'N	137°08'W	60.4	220	11	65.7	60.2	1022	02	6	7	9	2	220	1	-	-
40	0530	6/23	40°52'N	136°28'W	60.0	240	15	60.0	59.0	1023	50	6	8	7	3	240	1	33.08	0.63
41	1130	6/23	41°22'N	135°46'W	59.5	010	08	59.0	55.5	1024	01	8	2	8	3	230	1	-	-
42	1730	6/23	41°58'N	135°04'W	59.5	350	11	59.1	53.0	1026	03	6, 8	4	9	3	350	4	32.97	0.43
43	2330	6/23	41°10'N	135°04'W	61.5	350	09	60.0	54.0	1026	01	6	6	9	3	340	1	-	-
44	0530	6/24	40°33'N	135°04'W	61.0	300	06	60.5	55.0	1026	03	6, 5	4	8	3	340	1	33.33	0.58
45	1130	6/24	39°48'N	135°01'W	62.5	410	11	60.8	54.5	1028	00	8	4	5	3	XX	X	-	-
46	1730	6/24	38°59'N	134°59'W	63.5	050	11	60.5	55.0	1030	03	8	8	8	2	090	1	33.60	0.27
47	2330	6/24	39°20'N	134°57'W	62.5	040	06	66.4	59.0	1026	01	6	6	8	2	350	1	-	-
48	0530	6/25	39°56'N	134°58'W	63.0	030	05	59.8	55.0	1026	01	6, 8, 1	2	7	1	300	2	33.66	-
49	1500	6/25	39°58'N	134°52'W	62.5	110	02	63.0	58.0	1024	02	6	2	8	1	140	1	33.48	0.59
50	2330	6/25	38°55'N	134°50'W	65.8	350	07	66.8	59.8	1024	01	8	4	9	1	090	2	-	-
51	0500	6/26	38°30'N	134°35'W	64.8	350	07	64.0	59.0	1024	02	8	5	9	2	350	1	33.69	-
52	1500	6/26	38°30'N	134°32'W	64.0	150	08	63.2	59.2	1023	02	8, 6	6	9	2	170	3	33.77	0.55
53	2330	6/26	37°36'N	134°00'W	65.5	350	10	67.0	62.0	1026	02	8, 6	2	9	2	010	1	-	-
54	0530	6/27	36°50'N	133°52'W	65.5	320	08	65.0	63.0	1024	03	6	6	8	2	350	1	33.80	0.54
55	1530	6/27	36°44'N	133°48'W	65.5	330	08	67.5	65.5	1023	03	6	8	8	2	350	1	-	-
56	2330	6/27	35°49'N	133°47'W	66.5	350	11	69.0	66.5	1022	02	6	7	8	2	350	1	33.80	-
57	0530	6/28	35°01'N	133°43'W	68.1	340	13	66.8	65.5	1021	45	9	9	1	4	340	4	33.89	0.29
58	1130	6/28	34°14'N	133°39'W	66.5	340	14	66.0	65.0	1020	01	6	3	8	2	340	1	-	-
59	1730	6/28	33°25'N	133°36'W	67.5	350	23	68.5	66.0	1021	20	6, 8	6	8	4	010	3	34.14	0.36
60	2330	6/28	32°38'N	133°31'W	68.1	200	15	69.5	69.5	1020	03	6	6	6	4	040	4	-	-
61	0530	6/29	31°58'N	133°28'W	67.5	040	25	64.0	67.7	1020	20	6	8	7	4	040	4	34.00	0.33
62	1130	6/29	31°12'N	133°25'W	66.0	070	14	68.5	63.5	1019	02	6	8	7	4	090	3	-	-
63	1730	6/29	31°13'N	132°57'W	66.8	170	19	66.0	61.0	1020	02	6	8	7	5	000	3	33.93	0.37
64	2330	6/29	31°33'N	132°17'W	67.0	050	18	67.0	62.0	1020	02	6	8	7	5	040	3	-	-
65	0530	6/30	31°53'N	131°37'W	66.0	050	18	66.0	61.5	1021	02	6	8	6	4	040	3	33.82	0.29
66	1130	6/30	32°14'N	130°58'W	65.9	050	18	65.0	60.2	1020	02	X	X	6	5	XX	4	-	-
67	1730	6/30	32°35'N	130°19'W	65.5	050	18	65.0	59.0	1022	02	6	8	7	5	040	4	33.86	0.42
68	2330	6/30	32°55'N	129°38'W	65.5	010	18	64.5	59.5	1021	02	6	8	7	5	020	4	-	-
69	0530	7/1	33°14'N	128°57'W	64.2	330	15	64.5	59.5	1022	02	6, 8	8	6	5	350	5	33.24	0.45
70	1130	7/1	33°34'N	128°14'W	63.0	340	18	63.0	57.0	1021	02	6, 8	8	7	5	360	4	-	-

Table 4.--Summary of observations at bathythermograph lowerings, *John R. Manning* cruise 36 (NEPAS) (for coded values see H. O. Pub. 606-c) (cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
71	1730	7/1	33°53'N	127°31'W	62.5	350	18	63.0	58.5	1022	02	6	6	8	5	350	4	33.46	0.38
72	2330	7/1	34°15'N	126°47'W	63.5	310	19	64.2	61.3	1021	01	1,6,8	3	9	4	020	4	-	-
73	0530	7/2	34°25'N	126°26'W	63.3	350	14	63.5	58.5	1021	01	1,6,8	3	9	3	350	1	33.24	0.43
74	1450	7/2	34°26'N	126°32'W	63.0	320	18	62.0	58.0	1021	02	1,6,8,4	5	9	3	010	2	-	1.08
75	1730	7/2	34°35'N	126°10'W	62.5	320	18	62.5	58.0	1021	01	6,8	4	9	3	010	2	33.21	0.89
76	2330	7/2	34°48'N	125°32'W	61.5	340	18	63.5	59.0	1021	02	6,8	3	9	3	010	2	-	-
77	0530	7/3	34°58'N	125°15'W	61.5	320	16	61.5	59.0	1020	02	6,8	3	9	5	310	3	33.48	0.47
78	1130	7/3	34°56'N	126°18'W	61.6	020	20	61.5	57.8	1021	02	6,8	3	5	5	350	4	-	-
79	1730	7/3	34°56'N	127°06'W	62.5	340	17	64.0	59.5	1024	02	6,8	3	8	4	010	4	33.04	0.39
80	2330	7/3	34°56'N	127°59'W	64.0	020	20	65.0	61.0	1024	03	6,8	7	8	5	000	4	-	-
81	0530	7/4	34°57'N	128°52'W	63.1	000	23	63.0	59.0	1024	01	6	5	7	5	000	4	33.75	0.37
82	1130	7/4	34°60'N	129°47'W	64.5	320	20	64.0	58.0	1023	02	6	7	7	4	010	4	-	-
83	1130	7/4	35°02'N	130°41'W	64.5	350	20	64.0	58.5	1024	02	6,4	7	7	5	010	4	33.66	0.36
84	2330	7/4	35°05'N	131°37'W	64.4	330	18	64.5	60.2	1023	02	6,4	7	7	5	010	4	-	-
85	0530	7/5	35°08'N	132°23'W	65.5	350	14	64.0	58.5	1024	02	6,8	8	7	4	020	4	33.89	-
86	1130	7/5	35°32'N	131°46'W	65.0	350	16	63.5	59.0	1022	02	6	8	7	4	010	4	-	-
87	1730	7/5	35°59'N	131°05'W	64.0	330	15	63.5	61.0	1022	46	6,4	9	3	4	000	4	33.40	0.29
88	2330	7/5	36°23'N	130°33'W	64.5	360	14	64.0	61.0	1021	01	6,8	5	8	3	010	4	-	-
89	0530	7/6	36°36'N	130°12'W	63.5	310	08	62.5	61.0	1022	03	0,6	6	5	3	350	1	33.15	0.55
90	1530	7/6	36°42'N	130°14'W	62.6	350	17	62.5	61.0	1023	00	0,6	7	6	3	350	1	33.08	0.74
91	1730	7/6	36°50'N	129°59'W	63.0	350	13	62.7	60.0	1023	01	8	5	9	2	350	1	33.06	-
92	2330	7/6	37°09'N	129°26'W	63.5	330	18	64.0	61.0	1023	03	6	8	X	X	340	X	-	-
93	0355	7/6	37°20'N	129°10'W	63.0	340	09	63.5	59.0	1023	02	6	7	8	3	200	1	33.37	0.61
94	1800	7/7	37°27'N	129°03'W	63.0	350	10	64.5	61.0	1024	01	8	2	8	3	000	1	33.37	0.56
95	2330	7/7	37°47'N	128°32'W	62.0	350	11	64.5	61.0	1023	02	X	0	9	3	020	1	-	-
96	0530	7/8	38°10'N	127°03'W	62.0	350	10	62.5	57.0	1023	02	X	0	9	3	000	1	32.99	0.24
97	1130	7/8	38°34'N	127°22'W	61.5	350	13	63.5	60.0	1022	02	X	0	9	3	000	1	-	-
98	1730	7/8	38°58'N	126°49'W	61.9	320	15	63.3	60.0	1022	02	8	6	9	3	000	1	32.94	0.36
99	2330	7/8	39°22'N	126°17'W	61.5	340	15	62.5	59.5	1021	02	2	8	9	3	000	4	-	-
100	0530	7/9	39°37'N	125°34'W	59.5	350	18	62.0	59.5	1020	02	0	0	9	3	000	3	33.08	-
101	1130	7/9	39°59'N	124°54'W	52.5	000	14	57.5	55.0	1020	02	0	0	7	3	000	1	-	-
102	1730	7/9	39°59'N	125°46'W	61.5	330	12	63.5	62.0	1021	02	8	5	8	3	310	1	33.01	0.36
103	2330	7/9	39°59'N	126°38'W	62.0	330	09	62.5	60.0	1021	02	6	1	8	3	330	1	-	-
104	0355	7/10	39°60'N	126°51'W	62.4	310	08	64.7	61.5	1020	02	8	1	9	2	310	1	32.99	0.45
105	1500	7/10	40°03'N	126°54'W	62.5	300	12	65.0	63.0	1018	03	6	8	7	3	310	1	-	0.45

Table 4.--Summary of observations at bathythermograph lowerings, John R. Manning cruise 36 (NEPAS) (for coded values see H. O. Pub. 606-c) (cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
106	1730	7/10	40°02'N	127°07'W	62.5	300	12	65.5	63.0	1018	02	6	8	7	3	310	1	32.99	-
107	2330	7/10	40°02'N	127°50'W	62.2	280	15	64.2	60.2	1018	01	6	6	8	5	250	3	-	-
108	0530	7/11	40°20'N	128°33'W	63.0	280	15	63.0	59.0	1021	02	6	5	8	4	250	3	32.92	0.46
109	1130	7/11	40°03'N	129°20'W	62.0	340	13	63.0	59.5	1023	02	6	6	8	4	340	4	-	-
110	1730	7/11	40°04'N	130°06'W	62.5	050	06	65.0	58.2	1024	02	1,4,6	6	9	3	360	5	33.08	0.51
111	2330	7/11	40°08'N	131°07'W	64.0	100	07	68.5	60.0	1023	02	1,4,6	3	9	2	340	1	-	-
112	0530	7/12	40°11'N	131°50'W	63.3	150	10	64.0	60.0	1020	02	6,1	2	9	3	170	1	33.12	0.39
113	1130	7/12	40°01'N	132°36'W	63.0	140	20	65.0	62.3	1015	00	6	8	8	2	090	2	-	-
114	1730	7/12	39°52'N	133°22'W	63.5	240	10	65.0	63.0	1009	21	6	8	7	3	240	3	33.12	0.36
115	2330	7/12	40°17'N	132°43'W	63.0	180	13	66.0	64.0	1008	02	6	8	7	4	210	4	-	-
116	0530	7/13	40°35'N	132°13'W	62.5	240	11	64.3	62.0	1006	03	6	6	7	5	230	4	33.15	0.68
117	1130	7/13	41°05'N	131°29'W	62.5	240	16	62.5	60.5	1005	02	1,6,8	6	7	3	230	2	-	-
118	1730	7/13	41°31'N	130°44'W	62.0	250	05	64.0	60.5	1005	02	5,6,8	4	8	4	220	1	32.88	0.96
119	2330	7/13	41°59'N	129°58'W	62.5	240	14	64.2	61.0	1007	02	6,8	6	8	3	240	2	-	-
120	0530	7/14	42°22'N	129°21'W	61.5	300	18	61.0	58.0	1009	03	6,8	8	8	3	240	2	32.84	0.38
121	1730	7/14	42°39'N	128°42'W	61.8	290	17	62.0	58.0	1016	01	6	6	8	6	240	5	32.88	0.52
122	2330	7/14	43°04'N	128°09'W	62.5	290	21	62.5	58.0	1020	02	6,8	5	8	5	260	4	-	-
123	0530	7/15	43°22'N	127°50'W	62.0	280	06	62.0	57.0	1023	02	6,8	5	8	5	260	5	32.39	0.48
124	1130	7/15	43°49'N	127°07'W	60.0	290	16	59.1	55.1	1022	02	6,8	4	7	3	260	4	-	-
125	1730	7/15	44°16'N	126°45'W	62.0	320	14	60.0	56.0	1023	02	8	2	9	3	350	1	32.34	0.38
126	2330	7/15	44°50'N	126°15'W	63.0	330	12	65.0	63.5	1026	02	8,4,5	5	9	3	260	1	-	-
127	0530	7/16	45°23'N	125°39'W	62.0	340	13	61.5	58.0	1023	02	6,8	3	7	3	020	1	30.77	0.45
128	1130	7/16	45°45'N	124°42'W	62.5	340	15	60.0	55.0	1022	02	6,8	4	8	3	010	1	-	-
129	0530	7/23	45°22'N	125°11'W	62.5	330	01	63.5	61.5	1019	02	6	6	8	3	330	1	31.49	0.45
130	1130	7/23	44°49'N	125°59'W	62.5	340	09	62.0	60.0	1021	50	6	6	7	1	280	1	-	-
131	1730	7/23	44°18'N	126°43'W	63.0	340	08	61.0	58.5	1023	21	6	9	6	2	300	1	30.39	0.39
132	2330	7/23	43°51'N	127°22'W	62.5	320	11	63.5	61.5	1025	01	6	6	8	3	320	1	32.84	0.63
133	0530	7/24	43°42'N	127°53'W	61.5	340	09	60.5	56.0	1025	02	8	3	8	3	340	1	32.92	0.74
134	1130	7/24	43°42'N	127°53'W	62.0	320	15	62.5	56.5	1024	02	8	3	8	2	340	1	32.54	0.46
135	1530	7/24	43°43'N	127°51'W	61.5	330	12	61.0	57.0	1024	02	8,4,6	5	8	2	340	1	32.70	0.55
136	2330	7/24	43°14'N	127°12'W	63.1	330	12	63.0	57.5	1022	02	8	3	9	3	330	2	-	-
137	0530	7/25	42°51'N	127°51'W	62.0	330	14	62.0	57.0	1021	02	8,1	3	9	3	340	2	32.61	0.64
138	1130	7/25	42°29'N	128°32'W	XXX	210	13	62.0	58.5	1011	02	8	2	9	3	330	1	33.04	1.07
139	1730	7/25	42°06'N	129°12'W	61.9	320	15	62.5	59.2	1020	03	8,6,4	6	9	3	300	2	32.94	0.61
140	2330	7/25	41°38'N	129°55'W	62.5	320	21	62.5	58.5	1021	03	6,8	6	8	4	300	2	33.10	0.90

Table 4.--Summary of observations at bathythermograph lowerings, John R. Manning cruise 36 (NEPAS) (for coded values see H. O. Pub. 606-c) (cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Baro-meter, mb.	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
141	0530	7/26	41°13'N	130°27'W	62.0	300	21	61.5	56.5	1024	03	6	8	8	5	300	4	33.01	0.61
142	1130	7/26	40°28'N	130°45'W	62.0	000	18	62.5	55.0	1024	02	6	2	7	5	000	4	32.99	0.55
143	1730	7/26	40°52'N	131°10'W	62.0	000	21	61.0	55.5	1025	02	6	7	5	5	000	4	32.99	2.20
144	2330	7/26	40°03'N	131°19'W	63.0	330	18	64.0	58.5	1025	02	6, 8	3	8	5	330	4	33.15	-
145	0530	7/27	39°39'N	131°16'W	62.5	000	16	63.0	59.0	1025	01	6	6	7	5	000	4	33.13	0.53
146	1130	7/27	38°51'N	131°11'W	63.0	000	14	62.5	58.5	1025	02	6	7	8	4	000	4	32.26	0.69
147	1730	7/27	38°18'N	130°53'W	68.5	320	17	63.0	60.5	1024	18	6	7	8	5	000	4	-	0.38
148	2330	7/27	38°26'N	130°17'W	64.0	310	11	65.0	62.2	1023	01	6	6	7	3	350	3	33.10	0.42
149	0530	7/28	38°35'N	129°41'W	63.5	030	16	63.5	61.0	1022	02	6	8	7	4	030	3	33.04	0.30
150	1130	7/28	38°43'N	129°04'W	62.0	330	10	63.0	61.0	1019	01	6	2	7	5	010	3	33.15	-
151	1730	7/28	38°47'N	128°37'W	62.7	330	16	62.0	60.5	1020	50	X	9	3	5	030	3	33.10	0.61
152	2330	7/28	38°49'N	128°40'W	63.0	350	16	63.0	60.5	1019	01	8	5	8	4	330	3	33.12	0.44
153	0400	7/29	38°45'N	128°38'W	62.5	310	15	64.5	61.0	1018	01	8	1	8	3	300	1	33.17	0.45
154	1130	7/29	38°45'N	128°35'W	62.5	200	06	64.0	62.5	1017	00	X	2	6	2	320	1	33.19	0.53
155	1600	7/29	38°46'N	128°37'W	62.8	280	03	62.7	60.5	1017	02	8	7	8	2	300	1	33.10	0.47
156	2330	7/29	38°56'N	127°51'W	63.5	340	11	65.0	62.0	1017	03	6	6	8	3	010	1	33.19	0.63
157	0905	7/30	39°01'N	127°32'W	63.2	330	08	65.0	62.2	1018	01	6, 8	7	8	2	290	1	33.10	0.57
158	1130	7/30	39°01'N	127°32'W	62.8	340	17	63.0	58.0	1019	02	8	7	8	3	300	1	32.99	0.44
159	1700	7/30	39°03'N	127°33'W	62.0	010	12	63.5	58.0	1021	02	6	8	8	3	320	1	33.06	0.52
160	2400	7/30	39°01'N	127°22'W	62.8	320	12	63.0	58.0	1020	02	6	6	9	3	320	1	33.37	0.67
161	0530	7/31	39°00'N	127°27'W	62.2	340	20	62.0	57.5	1020	02	6	2	9	3	340	1	33.15	0.61
162	1230	7/31	39°00'N	127°26'W	62.0	330	16	62.5	59.0	1020	02	6	3	9	3	320	1	33.17	-
163	1830	7/31	38°59'N	127°28'W	62.5	350	14	63.0	60.0	1022	02	8	2	9	2	350	1	33.10	0.89
164	2300	7/31	38°59'N	127°28'W	63.0	330	12	65.0	60.0	1022	02	6, 8	3	3	3	330	1	33.01	0.82
165	2330	8/2	39°14'N	127°31'W	62.0	340	19	64.0	60.1	1020	03	6	5	8	6	000	6	33.04	1.90
166	0300	8/3	39°02'N	127°31'W	62.6	350	17	63.0	60.0	1019	02	6	4	9	5	000	4	33.01	1.30
167	1730	8/3	38°57'N	127°12'W	59.8	280	09	64.8	61.8	1017	46	2, 6	8	6	2	310	1	33.12	3.46
168	2330	8/3	38°54'N	127°04'W	59.8	290	09	64.0	60.5	1016	02	2, 6	3	7	3	300	1	33.35	4.92
169	0530	8/4	38°55'N	126°30'W	61.3	300	11	62.0	60.0	1016	36	6	6	7	3	300	1	32.95	2.32
170	1730	8/4	38°56'N	125°42'W	61.8	230	09	63.0	60.5	1014	02	8	1	9	2	270	1	33.21	3.94
171	2330	8/4	38°58'N	126°11'W	61.3	250	11	64.0	61.0	1016	03	8, 4, 6, 8	3	9	6	290	8	-	-
172	0530	8/5	38°50'N	126°36'W	60.5	270	06	63.0	60.5	1016	02	4	2	9	5	300	5	32.94	0.46
173	1130	8/5	38°31'N	126°02'W	61.5	270	11	62.5	59.5	1015	02	4	1	9	4	300	4	32.90	0.78
174	1730	8/5	38°15'N	125°41'W	55.1	310	04	61.0	58.5	1017	03	6	1	9	4	340	5	33.04	-
175	2040	8/5	38°06'N	125°25'W	58.0	270	07	63.0	59.2	1017	01	1, 2	6	9	5	300	5	33.33	-

Table 4.--Summary of observations at bathythermograph lowerings, John R. Manning cruise 36 (NEPAS) (for coded values see H. O. Pub. 606-c) (cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
176	2330	8/5	38°14'N	125°44'W	56.5	270	09	63.0	59.5	1018	02	6	1	9	5	300	5	33.00	1.16
177	0530	8/6	38°07'N	125°48'W	56.8	250	11	60.5	58.0	1018	03	6, 8	5	7	4	300	4	33.39	2.19
178	1130	8/6	37°38'N	125°30'W	60.0	310	11	62.3	60.0	1018	01	6	3	8	3	300	2	33.19	-
179	1730	8/6	37°07'N	125°07'W	60.9	330	09	63.0	60.2	1019	01	6	7	9	2	350	2	33.06	0.61
180	2005	8/6	36°59'N	124°58'W	59.3	320	12	64.0	60.0	1019	02	6	7	9	2	350	2	33.37	-
181	2210	8/6	36°53'N	124°48'W	59.5	300	06	64.5	60.5	1019	02	6	3	9	2	350	2	-	-
182	2330	8/6	36°45'N	124°35'W	60.1	300	06	64.0	60.0	1019	02	6	1	9	2	350	2	33.73	2.40
183	0400	8/7	36°45'N	124°34'W	59.5	300	12	61.1	60.0	1018	02	X	0	9	2	350	2	33.55	1.07
184	1130	8/7	36°42'N	124°29'W	59.0	320	11	60.0	60.0	1017	45	X	0	1	2	320	2	33.49	1.04
185	1730	8/7	36°35'N	124°18'W	60.5	260	06	64.0	63.0	1019	28	6	8	5	2	300	1	33.49	1.93
186	2330	8/7	36°13'N	123°38'W	62.0	300	04	64.5	62.0	1018	03	6	6	6	2	300	1	33.51	0.82
187	0452	8/8	36°09'N	123°29'W	60.2	300	10	63.0	60.1	1017	40	6	8	8	2	300	2	33.62	0.91
188	1130	8/8	36°08'N	123°24'W	60.2	300	08	62.0	59.5	1018	02	6	8	8	2	300	2	34.22	-
189	1600	8/8	36°09'N	123°24'W	60.5	310	12	62.5	59.5	1019	02	6	8	6	2	300	2	33.60	0.97
190	2330	8/8	35°20'N	123°23'W	61.5	320	11	64.8	61.0	1018	02	4, 6	5	9	2	320	1	33.60	0.45
191	0530	8/9	34°48'N	123°22'W	61.7	310	18	62.5	59.5	1017	02	6	1	9	2	300	1	34.78	1.04
192	1730	8/9	34°47'N	123°44'W	61.0	320	13	63.0	60.0	1017	03	1, 6	2	9	3	320	1	44.04	0.50
193	2200	8/9	34°49'N	124°10'W	63.0	320	16	64.8	61.0	1017	02	8	3	9	3	320	1	33.12	0.50
194	2330	8/9	34°49'N	124°10'W	63.0	320	20	64.2	60.5	1016	02	8	1	9	4	300	1	33.19	0.58
195	0230	8/10	34°48'N	124°11'W	62.5	320	21	63.0	61.0	1015	03	8	8	7	4	300	4	33.26	0.64
196	1130	8/10	34°27'N	125°13'W	62.5	340	22	62.0	59.5	1016	02	6	8	7	5	340	4	33.33	-
197	1730	8/10	34°18'N	126°06'W	63.8	340	20	70.0	60.5	1018	02	8	4	8	4	340	1	33.30	-
198	2330	8/10	34°12'N	126°52'W	65.5	000	19	66.5	61.0	1017	02	6, 1	6	8	4	010	1	33.40	0.41
199	0530	8/11	34°04'N	127°37'W	65.0	010	17	65.0	61.2	1017	02	6, 8	6	7	4	010	4	33.49	0.66
200	1130	8/11	33°51'N	128°24'W	66.5	000	17	65.0	61.0	1017	02	6, 8	4	8	4	000	2	-	-
201	1730	8/11	33°42'N	129°15'W	66.0	020	21	67.5	63.0	1020	02	6, 8	8	8	4	000	2	33.49	0.39
202	2330	8/11	33°33'N	130°03'W	66.6	000	12	68.0	63.2	1020	02	6	8	9	3	000	1	33.51	-
203	0530	8/11	33°22'N	130°52'W	67.5	000	12	67.5	63.2	1021	02	6	5	8	3	000	1	-	1.11
204	1130	8/12	33°11'N	131°39'W	68.0	000	12	64.5	64.0	1021	02	6, 8	6	8	3	000	1	34.00	-
205	1730	8/12	33°00'N	132°28'W	68.2	040	16	68.5	64.0	1022	02	6	8	9	3	040	1	34.52	0.32
206	2330	8/12	32°39'N	133°07'W	69.0	040	12	69.0	62.7	1022	02	6	5	9	3	040	1	34.76	0.56
207	0530	8/13	32°19'N	133°59'W	68.7	040	12	69.5	64.0	1023	02	8	3	9	3	050	1	34.20	0.45
208	1130	8/13	32°01'N	134°50'W	69.0	050	13	68.5	63.5	1023	02	6	8	8	3	050	1	34.52	-
209	1730	8/13	31°41'N	135°49'W	69.8	040	14	70.0	62.0	1024	03	6	8	7	3	040	1	36.09	-
210	2330	8/13	31°23'N	136°38'W	70.3	040	13	71.5	66.0	1022	01	8, 4	2	8	3	030	1	34.90	-

Table 4.--Summary of observations at bathythermograph lowerings, John R. Manning cruise 36 (NEPAS) (for coded values see H. O. Pub. 606-c) (cont'd)

Ser. No.	Time, GCT	Date, 1957	Latitude	Longitude	Bkt. temp., °F.	Wind		Air temp.		Barometer, mb.	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., ‰	Surf. PO_4-P, µg at./L.
						Dir., °T.	Force, kt.	Dry bulb, °F.	Wet bulb, °F.			Type	Cover			Dir. °T.	Amt.		
211	0530	8/14	31°00'N	137°31'W	69.2	050	14	70.2	63.1	1023	02	1,4,8	5	7	3	040	2	34.99	-
212	1130	8/14	30°36'N	138°22'W	69.8	040	17	69.8	62.6	1022	02	1,6,8	5	8	3	040	2	35.05	-
213	1830	8/14	30°10'N	139°22'W	70.7	040	09	72.0	64.5	1023	02	3,8,2	6	8	3	040	1	35.21	0.34
214	2330	8/14	29°51'N	140°04'W	71.6	040	09	74.3	65.5	1021	02	4,8	6	9	3	040	2	35.12	-
215	0530	8/15	29°27'N	140°52'W	72.5	040	10	71.0	64.0	1021	02	4,8	6	8	3	040	2	-	-
216	1200	8/15	29°04'N	141°40'W	71.5	070	13	69.7	64.0	1020	02	6,4	6	8	3	040	1	-	-
217	1815	8/15	28°38'N	142°34'W	72.2	070	19	72.5	65.5	1020	02	4,6,8	5	9	3	080	4	35.41	0.25
218	2330	8/15	28°19'N	143°16'W	73.5	020	16	73.0	66.0	1019	02	2,6	6	8	3	020	2	-	-
219	0530	8/16	27°56'N	144°04'W	73.5	070	17	72.5	67.5	1019	02	6,5	5	8	3	100	1	-	-
220	1130	8/16	27°29'N	144°48'W	74.8	080	13	71.2	67.0	1020	03	8	2	8	3	340	2	-	-
221	1830	8/16	26°50'N	145°32'W	73.0	080	14	73.0	67.5	1021	02	8	4	8	3	320	2	-	-
222	2330	8/16	26°36'N	146°17'W	73.5	070	12	74.5	68.0	1020	02	8,5,1	2	8	3	100	1	-	-
223	0530	8/17	26°12'N	147°07'W	74.6	100	14	73.5	69.2	1020	02	8	6	7	3	100	2	-	-
224	1130	8/17	25°52'N	147°58'W	74.0	090	12	73.5	67.0	1020	02	8	5	8	3	090	2	-	-
225	1130	8/17	25°32'N	148°50'W	74.3	070	16	75.3	68.0	1022	02	6,8,5	5	8	4	070	3	-	-
226	2330	8/17	25°11'N	149°41'W	75.4	070	17	78.8	71.0	1021	02	6,8	6	9	4	080	3	-	-
227	0530	8/18	24°47'N	150°29'W	75.0	080	20	74.5	70.0	1021	02	8,4	5	8	3	080	2	-	-
228	1130	8/18	24°23'N	151°19'W	75.0	070	17	74.5	70.5	1021	01	8	2	8	4	010	1	-	-
229	1730	8/18	24°01'N	152°08'W	75.9	070	15	75.8	71.0	1020	02	1,6,8	6	9	3	070	4	-	-
230	2330	8/18	23°39'N	152°56'W	77.5	070	18	78.2	72.8	1019	02	8,6	3	8	3	070	4	-	-
231	0530	8/19	23°13'N	153°42'W	76.0	070	21	76.5	72.0	1018	18	6	6	8	4	070	4	-	-
232	1130	8/19	22°51'N	154°30'W	77.0	070	18	75.5	72.2	1018	02	1,6	2	7	4	070	4	-	-
233	1730	8/19	22°29'N	155°18'W	77.0	070	21	78.4	71.5	1018	02	8,6	3	7	4	070	4	-	-
234	2330	8/19	22°07'N	156°07'W	78.0	070	23	77.5	73.0	1018	02	6,8	6	7	4	070	4	-	-
235	0530	8/20	21°40'N	156°54'W	77.4	090	19	78.0	73.0	1016	03	6,8,1,4	6	7	5	100	4	-	-

Table 5.--Weather observations (USWB 1210-F), Hugh M. Smith cruise 40 (NEPAS)[1]

Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
7/3	22.6°N	156.6°W	0000	99	02	19	02	2	1019.6	6	1.0	77.9	71.9	76.7	5	5	4	5	0	0	04	3	5
7/3	23.2°N	156.3°W	0600	99	06	22	02	2	1020.7	2	1.4	76.8	70.3	76.3	8	8	4	5	X	X	XX	X	X
7/3	23.6°N	156.0°W	1200	99	07	18	61	X	1019.3	8	1.4	75.5	72.1	78.0	X	X	X	X	X	X	XX	X	X
7/3	24.0°N	155.5°W	1800	99	06	17	02	1	1020.7	2	2.4	77.2	72.8	76.8	2	2	1	5	0	0	06	3	2
7/4	24.6°N	154.8°W	0000	99	06	14	60	0	1019.3	7	0.7	78.8	72.2	76.0	3	2	2	5	0	0	06	2	2
7/4	25.2°N	154.1°W	0600	99	08	16	02	0	1020.3	2	1.7	76.7	71.3	75.8	3	3	2	5	0	0	06	2	2
7/4	25.9°N	153.4°W	1200	99	09	15	02	X	1020.7	7	1.4	75.4	70.6	75.8	X	X	X	X	X	X	XX	X	X
7/4	26.6°N	152.7°W	1800	99	07	11	02	0	1023.0	2	1.4	75.3	70.8	74.8	2	1	2	4	7	0	09	3	2
7/5	26.8°N	152.5°W	0000	99	08	14	02	0	1022.7	2	0.3	78.6	71.8	75.6	3	2	1	4	7	8	04	3	2
7/5	26.4°N	151.8°W	0600	99	09	15	03	1	1024.0	2	2.7	76.0	71.0	75.9	4	4	4	4	0	0	07	3	2
7/5	28.2°N	151.3°W	1200	99	08	15	50	5	1024.7	7	0.3	73.9	69.2	75.1	X	X	X	X	X	X	XX	X	X
7/5	28.9°N	150.8°W	1800	99	07	18	02	1	1026.4	2	2.7	73.8	69.6	74.4	X	2	1	4	0	0	06	3	3
7/6	29.2°N	150.5°W	0000	99	08	14	02	1	1026.2	4	0.2	76.9	70.4	74.2	X	1	1	4	0	0	08	2	2
7/6	30.0°N	150.0°W	0600	99	03	13	50	2	1026.2	2	0.3	72.8	67.2	73.8	8	8	4	4	X	X	07	2	2
7/6	30.7°N	149.4°W	1200	98	07	20	00	2	1025.7	7	1.0	71.8	67.6	72.9	8	8	X	X	X	X	XX	X	X
7/6	31.1°N	149.0°W	1800	99	03	13	02	2	1026.4	2	1.7	72.5	65.3	72.7	8	8	8	4	X	X	03	2	1
7/7	32.1°N	148.4°W	0000	99	06	14	02	2	1026.4	6	0.3	75.5	68.4	73.5	6	5	4	3	2	0	06	3	2
7/7	32.8°N	147.8°W	0600	99	08	07	01	1	1026.4	2	0.3	72.7	68.3	73.0	2	2	2	4	0	0	05	2	2
7/7	33.6°N	147.2°W	1100	98	06	07	01	1	1025.7	8	1.0	70.2	65.6	71.6	2	X	X	X	X	X	XX	X	X
7/7	34.3°N	146.6°W	1800	99	02	08	03	0	1026.1	1	1.0	70.0	65.8	70.9	3	3	2	4	0	0	03	3	1
7/8	35.1°N	146.1°W	0000	99	03	01	02	0	1025.1	8	1.0	74.4	65 6	75.3	1	1	4	5	0	0	02	2	0
7/8	35.8°N	145.6°W	0600	99	25	09	03	0	1024.7	3	0.2	71.3	66.8	71.3	2	2	4	4	0	0	XX	X	X
7/8	36.8°N	144.9°W	1200	99	26	15	02	0	1024.0	7	1.0	69.8	67.7	69.0	2	2	2	4	0	0	XX	X	X
7/8	37.2°N	144.5°W	1800	99	27	10	02	0	1023.4	2	0 7	68.7	66.6	68.3	2	1	1	4	0	5	29	2	2
7/9	38.2°N	143.9°W	0000	99	21	13	03	0	1022.0	7	1.4	71.6	68.8	66.9	3	1	1	4	7	5	23	2	1
7/9	38.8°N	143.1°W	0600	96	25	23	63	1	1018.6	7	1.0	68.1	67.0	66.0	8	8	7	4	X	X	26	5	2
7/9	39.7°N	142.7°W	1200	97	26	23	63	6	1015.6	6	1.7	66.8	65.2	64.5	X	X	X	X	X	X	27	5	2
7/9	40.2°N	142.5°W	1800	99	26	16	01	2	1014.9	4	0.0	63.4	62.2	63.3	7	6	6	4	7	0	24	3	3
7/10	40.7°N	142.0°W	0000	98	03	25	15	5	1016.6	1	1.7	61.7	58.9	62.1	8	8	5	4	0	0	01	3	3
7/10	41.2°N	141.6°W	0600	99	02	21	01	2	1020.0	2	2.7	62.3	60.0	62.4	7	X	X	X	X	X	02	2	4
7/10	41.7°N	141.0°W	1200	98	00	12	01	1	1021.0	8	0.7	57.5	52.2	60.2	3	X	X	X	X	X	XX	X	3
7/10	42.2°N	140.6°W	1800	99	35	14	02	1	1022.7	1	0.9	57.8	55.1	59.0	8	8	5	4	X	X	01	2	3
7/11	43.2°N	139.5°W	0600	99	28	10	03	2	1022.7	2	0.3	57.5	53.6	59.2	8	8	6	4	X	X	33	2	1
7/11	43.8°N	138.7°W	1200	98	25	11	02	2	1020.7	7	1.4	57.7	53.5	57.8	8	8	6	4	X	X	XX	X	X
7/11	44.4°N	138.2°W	1800	99	24	11	02	2	1019.0	7	1.4	58.0	53.0	57.2	8	8	6	4	X	X	35	2	1
7/12	44.8°N	137.7°W	0000	99	16	14	02	2	1016.9	7	1.4	60.1	57.2	57.0	8	8	6	4	X	X	35	3	3
7/12	45.5°N	137.0°W	0600	98	15	14	50	5	1013.5	7	1.4	56.9	56.9	56.9	8	8	6	4	X	X	XX	X	X
7/12	44.4°N	136.9°W	1200	97	08	26	63	6	1006.4	7	3.4	57.0	57.0	57.0	8	8	X	X	X	X	XX	X	X

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[1] All columns in USWB 1210-F are not included here. Those deleted are:

Column	2	Day of week	Column	23	Course of ship
"	3	Octant	"	24	Speed of ship
"	13	Barometer as read	"	31	Diff. sea-air, °F.
"	14	Barometer as corrected	"	32	Dew point, °F.
"	17	Air temperature, °F.			

Table 5. --Weather observations (USWB 1210-F), *Hugh M. Smith* cruise 40 (NEPAS)(cont'd)

Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
7/12	44.3°N	136.8°W	1800	97	09	26	64	6	1001.0	7	2.4	57.8	57.7	57.3	8	8	7	4	X	X	15	2	4
7/13	43.8°N	136.4°W	0000	98	24	11	02	5	1001.7	2	0.4	59.1	58.5	58.7	8	8	5	4	X	X	18	2	3
7/13	43.1°N	136.2°W	0600	99	31	06	03	5	1002.4	2	1.0	61.3	58.9	59.3	8	8	5	4	X	X	XX	X	X
7/13	42.3°N	135.9°W	1200	98	29	10	02	6	1004.1	2	0.7	61.2	58.2	60.2	8	8	5	4	X	X	XX	X	X
7/13	41.7°N	135.4°W	1800	99	32	22	01	2	1008.5	2	2.4	62.4	57.7	61.1	8	8	5	4	X	X	32	3	4
7/14	40.9°N	134.9°W	0000	99	34	21	01	2	1011.9	2	1.7	62.8	58.0	62.7	5	8	5	4	X	X	33	3	4
7/14	40.6°N	134.7°W	0600	99	29	17	02	1	1015.9	2	2.0	61.8	59.2	62.7	4	4	4	4	0	0	31	4	5
7/14	40.2°N	134.2°W	1200	99	30	06	02	1	1018.3	2	0.7	64.2	59.8	62.9	2	2	4	4	0	0	XX	X	X
7/14	40.5°N	133.6°W	1900	99	32	09	03	1	1022.0	2	2.0	62.1	59.8	62.6	8	8	4	4	X	X	08	3	2
7/15	41.0°N	133.1°W	0000	99	31	09	01	2	1024.0	2	1.0	62.3	56.6	62.3	7	7	4	4	0	0	31	2	2
7/15	41.3°N	133.0°W	0600	99	28	10	02	2	1025.4	2	1.0	60.0	58.8	61.8	7	7	4	4	0	0	28	2	2
7/15	42.2°N	132.1°W	1200	99	31	19	00	X	1026.1	6	0.5	60.6	59.2	61.2	X	X	X	X	X	X	XX	X	X
7/15	42.9°N	131.8°W	1800	99	29	09	02	2	1027.4	2	1.0	58.7	55.4	60.8	8	8	4	4	X	X	31	2	2
7/16	43.4°N	131.3°W	0000	99	33	18	02	2	1027.8	7	0.3	60.0	58.1	60.5	5	5	4	4	0	0	34	2	2
7/16	43.7°N	131.0°W	0600	99	35	16	02	2	1028.1	2	1.0	59.4	58.2	59.8	4	4	4	4	0	0	XX	X	X
7/16	44.3°N	130.5°W	1200	99	35	16	01	1	1028.1	4	0.0	57.9	56.1	58.9	3	3	2	4	0	0	XX	X	X
7/16	44.6°N	130.2°W	1800	99	36	20	03	1	1029.1	2	0.7	58.9	57.1	58.6	8	7	4	4	6	0	36	2	2
7/17	45.0°N	129.8°W	0000	99	29	26	01	2	1029.1	8	1.0	59.3	51.4	58.8	5	3	2	4	6	0	30	2	1
7/17	45.2°N	129.2°W	0600	99	34	24	02	2	1028.8	2	0.3	58.8	57.6	60.2	6	6	2	4	0	0	34	2	3
7/17	45.5°N	128.3°W	1200	99	35	18	02	2	1026.8	6	0.3	58.2	57.0	61.0	8	8	4	3	X	X	35	2	3
7/17	45.7°N	127.4°W	1900	99	33	19	02	2	1025.1	8	1.0	59.7	56.4	61.3	7	5	2	4	6	0	35	2	3
7/18	45.8°N	126.6°W	0000	99	34	20	01	2	1023.0	7	1.4	60.2	57.3	60.1	7	6	2	4	6	0	34	2	4
7/18	45.8°N	126.1°W	0600	99	34	19	01	2	1021.3	8	1.0	60.7	58.3	61.7	4	4	2	4	0	0	34	2	4
7/18	46.3°N	125.5°W	1200	99	32	20	01	2	1019.0	7	0.7	59.9	58.0	60.5	3	3	4	4	0	0	34	2	4
7/22	47.0°N	125.8°W	1800	98	21	06	02	2	1016.9	1	0.7	59.4	56.2	61.1	8	8	5	3	X	X	33	2	1
7/23	47.0°N	126.6°W	0000	99	25	13	02	2	1016.6	3	0.3	62.8	60.3	61.8	6	5	5	3	0	0	31	2	1
7/23	47.0°N	127.0°W	0600	99	28	15	02	X	1019.0	2	2.0	60.5	57.2	61.2	X	X	X	X	X	X	XX	X	X
7/23	47.0°N	127.1°W	1200	99	28	05	01	5	1022.7	2	1.4	60.2	59.1	60.9	6	5	2	3	0	1	28	2	1
7/23	47.0°N	127.8°W	1900	99	27	09	01	1	1024.7	2	1.7	62.0	58.8	61.2	3	2	2	3	0	0	27	2	1
7/24	47.0°N	128.3°W	0000	99	27	07	01	0	1025.7	1	0.7	61.7	60.2	60.3	2	2	2	4	0	0	27	3	2
7/24	47.0°N	128.9°W	0600	99	27	04	01	1	1025.7	0	0.2	59.0	58.5	59.2	3	1	1	4	2	0	27	3	1
7/24	47.0°N	129.1°W	1200	99	27	10	01	1	1025.4	4	0.0	59.0	56.8	58.8	3	2	1	4	X	X	27	3	1
7/24	46.9°N	130.0°W	1800	99	25	10	02	1	1024.7	6	0.3	60.3	59.7	58.7	8	8	6	4	X	X	26	3	2
7/25	46.7°N	130.7°W	0000	99	24	12	02	2	1023.7	7	0.7	60.0	58.5	59.0	8	4	8	5	3	X	28	3	2
7/25	46.8°N	131.1°W	0600	99	20	13	02	X	1020.0	6	0.4	61.8	60.2	59.0	X	X	X	X	X	X	XX	X	X
7/25	46.8°N	131.1°W	1300	99	28	19	02	2	1017.6	5	1.0	59.1	58.3	58.7	5	5	2	4	0	0	28	2	3
7/25	46.8°N	131.8°W	1800	99	30	20	02	2	1020.3	1	1.4	59.9	57.0	58.1	6	4	2	4	5	0	28	3	3
7/26	46.8°N	132.8°W	0000	99	28	26	03	1	1022.4	2	0.7	59.8	56.2	58.5	6	4	2	4	5	0	28	3	3
7/26	46.9°N	133.2°W	0600	99	28	10	01	2	1022.4	1	0.5	57.8	55.0	57.7	5	5	2	4	5	0	28	2	3
7/26	47.0°N	134.0°W	1200	97	26	20	XX	2	1021.7	6	0.3	55.0	54.2	57.3	8	8	7	4	X	X	26	2	3
7/26	46.6°N	133.5°W	1900	97	16	24	XX	6	1018.6	4	0.0	60.0	59.5	57.9	8	8	7	4	X	X	23	2	3
7/27	46.5°N	132.5°W	0000	97	24	26	52	6	1018.0	6	0.3	62.1	62.1	59.4	8	8	7	4	X	X	24	2	3
7/27	46.2°N	131.8°W	0600	96	25	20	65	6	1018.3	2	0.7	60.2	60.2	58.2	8	8	X	0	X	X	XX	X	X
7/27	46.2°N	130.4°W	1800	97	25	16	42	4	1018.3	3	0.2	61.8	60.5	59.0	7	7	X	0	X	X	27	4	4
7/28	46.1°N	129.8°W	0000	98	22	14	03	2	1018.6	1	0.2	63.8	63.2	60.3	8	8	6	3	X	X	26	4	4
7/28	46.0°N	129.1°W	0600	96	22	18	45	4	1018.6	3	0.2	62.0	62.0	60.4	9	X	X	0	X	X	25	4	3
7/28	46.0°N	129.0°W	1200	97	23	20	45	4	1015.6	6	1.0	62.6	62.2	60.3	9	X	X	0	X	X	23	2	2
7/28	46.0°N	127.8°W	1800	97	22	18	45	4	1015.9	4	0.0	63.0	63.0	61.0	9	X	X	0	X	X	26	3	3
7/29	45.7°N	127.2°W	0000	96	24	11	XX	X	1015.9	2	0.7	63.2	63.2	62.5	9	8	6	X	X	X	26	3	3
7/29	45.2°N	126.8°W	0600	97	33	10	20	5	1017.3	2	0.7	62.0	62.0	63.2	8	8	6	2	X	X	26	3	3

Table 5.--Weather observations (USWB 1210-F), Hugh M. Smith cruise 40 (NEPAS)(cont'd)

					Wind		Weather		Pressure			Temperature			Clouds						Waves		
Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
7/29	45.3°N	127.0°W	1200	97	33	12	00	2	1017.3	4	0.0	61.1	59.8	63.0	8	8	6	2	X	X	26	3	2
7/29	44.5°N	126.1°W	1800	99	35	15	03	1	1018.0	2	0.3	63.4	62.0	64.6	5	5	6	2	0	0	26	3	2
7/30	44.1°N	125.6°W	0000	99	34	15	03	2	1018.3	4	0.0	64.3	60.3	64.4	7	6	6	4	6	0	28	3	3
7/30	44.0°N	125.3°W	0600	99	33	17	02	2	1018.3	1	0.5	62.6	61.0	60.8	7	7	2	X	X	X	28	2	2
7/30	43.7°N	125.5°W	1300	99	33	07	02	2	1018.0	3	0.0	61.5	60.8	60.2	4	4	2	2	X	X	28	2	2
7/30	43.5°N	125.7°W	1800	99	35	08	01	0	1019.6	1	0.7	67.1	63.8	59.0	2	1	1	5	8	0	29	3	2
7/31	43.3°N	126.3°W	0000	99	33	12	03	0	1020.7	4	0.0	65.1	62.5	64.3	4	3	2	5	1	0	33	3	2
7/31	43.0°N	126.8°W	0600	99	33	14	02	0	1021.3	3	0.7	62.9	60.7	64.0	3	3	2	5	0	0	31	3	2
7/31	42.7°N	127.6°W	1800	99	35	18	02	1	1023.7	2	1.4	66.3	62.9	63.5	6	5	2	4	2	0	34	2	2
8/1	42.4°N	128.5°W	0000	99	34	14	03	0	1024.7	2	0.3	64.7	62.5	63.6	2	2	2	3	X	X	34	3	1
8/1	42.3°N	129.0°W	0600	99	36	17	02	1	1026.8	2	1.7	62.5	61.0	62.6	6	6	2	4	0	0	35	3	1
8/1	42.2°N	129.1°W	1200	99	36	14	03	X	1026.1	6	0.3	63.9	61.1	62.5	6	5	5	5	2	0	36	2	1
8/1	42.0°N	129.9°W	1800	99	35	15	02	1	1027.4	2	1.0	63.8	61.8	62.7	6	5	5	5	2	0	02	2	1
8/2	41.7°N	130.5°W	0000	99	36	13	02	1	1027.4	7	0.7	64.8	60.2	63.4	2	2	1	5	0	0	01	2	2
8/2	41.6°N	131.0°W	0600	99	33	10	02	1	1027.8	3	0.3	62.8	60.2	63.2	6	6	1	5	0	0	01	2	2
8/2	41.5°N	130.7°W	1300	99	32	11	02	1	1026.1	7	1.0	62.6	61.3	63.0	1	1	X	5	X	X	01	2	2
8/2	41.4°N	129.7°W	1800	99	32	10	02	0	1025.4	4	0.0	63.3	60.8	62.8	2	2	2	5	0	0	02	2	1
8/3	41.3°N	129.0°W	0000	99	28	14	03	0	1022.7	6	1.5	63.9	61.0	63.8	8	8	5	4	X	X	01	2	1
8/3	41.3°N	128.4°W	0600	99	28	12	02	2	1020.7	7	1.4	63.0	61.9	63.0	8	8	5	4	X	X	34	2	1
8/3	41.3°N	128.2°W	1300	97	23	16	51	2	1014.9	6	1.4	65.7	65.7	62.7	9	9	X	0	X	X	22	2	1
8/3	41.2°N	127.0°W	1800	99	29	18	03	2	1015.6	4	0.0	64.0	62.1	62.6	7	7	5	4	0	0	26	3	2
8/4	41.1°N	126.7°W	0000	99	26	12	02	2	1014.9	7	0.7	66.2	63.8	59.6	2	2	5	4	X	X	26	3	2
8/4	41.0°N	126.0°W	0600	97	24	10	02	1	1014.2	2	0.3	64.9	63.3	60.3	9	X	X	X	X	X	XX	X	X
8/4	40.8°N	125.7°W	1300	99	22	10	00	X	1012.9	5	0.3	61.7	61.3	59.6	2	1	3	X	0	4	28	3	2
8/5	40.6°N	125.6°W	0000	99	20	13	01	6	1013.9	7	0.7	61.4	59.8	60.4	2	2	2	5	6	0	28	3	5
8/5	40.5°N	126.1°W	0600	99	22	12	00	X	1014.6	1	1.0	61.3	60.1	59.7	X	X	X	X	X	X	XX	X	X
8/5	40.3°N	126.4°W	1300	98	23	11	00	X	1014.6	4	0.0	61.9	60.4	59.7	X	X	X	X	X	X	XX	X	X
8/5	40.2°N	127.3°W	1800	99	30	13	02	2	1016.9	2	1.4	60.9	59.6	59.6	6	4	2	5	7	0	29	5	4
8/6	40.2°N	127.7°W	0000	99	31	15	02	2	1018.0	5	0.0	64.9	60.9	63.1	7	4	4	4	7	0	29	3	4
8/6	40.2°N	127.0°W	0600	99	32	14	02	2	1019.3	1	1.0	63.5	61.0	63.1	8	X	X	X	X	X	31	3	3
8/6	39.9°N	128.5°W	1300	98	24	10	50	5	1018.3	7	0.3	62.4	60.7	63.3	8	8	6	4	X	X	29	2	2
8/6	39.8°N	129.4°W	1900	97	27	10	15	5	1018.6	4	0.0	64.2	62.9	63.5	8	8	7	3	X	X	28	2	2
8/7	39.7°N	129.9°W	0000	97	30	15	02	2	1019.0	4	0.0	67.8	63.4	63.8	7	7	7	3	0	0	28	2	2
8/7	39.5°N	130.6°W	0600	98	30	15	02	2	1019.3	2	0.7	65.4	62.8	64.4	X	X	X	X	X	X	XX	X	X
8/7	39.5°N	131.0°W	1200	97	30	14	00	6	1019.3	4	0.0	63.6	60.2	63.9	X	X	X	X	X	X	XX	X	X
8/7	39.4°N	130.1°W	1900	98	30	11	02	2	1020.0	2	0.7	65.8	62.7	63.9	8	8	7	3	X	X	33	2	2
8/8	39.2°N	129.2°W	0000	99	35	04	01	5	1020.0	6	0.3	67.1	64.2	64.0	6	5	2	4	0	9	29	2	2
8/8	39.2°N	128.8°W	0600	99	31	14	02	2	1020.3	3	0.7	64.3	62.5	63.9	4	4	2	4	0	0	XX	X	X
8/8	39.1°N	128.7°W	1300	98	00	05	02	2	1020.3	4	0.0	63.0	59.8	63.6	X	X	X	X	X	X	XX	X	X
8/8	40.0°N	127.7°W	1800	99	31	10	02	5	1021.7	2	1.0	63.7	62.0	63.7	7	7	2	4	0	0	32	2	1
8/9	39.0°N	127.4°W	0100	99	35	09	01	1	1021.0	7	1.0	64.8	60.8	64.2	2	2	2	4	0	0	32	2	1
8/9	39.0°N	126.9°W	0700	99	33	08	02	0	1020.3	8	0.3	63.0	59.8	61.7	1	X	X	X	X	X	33	3	2
8/9	39.0°N	127.0°W	1200	99	29	10	02	1	1018.6	7	0.7	62.6	59.3	62.3	8	8	6	4	X	X	29	2	2
8/9	39.0°N	126.2°W	1800	99	36	13	28	2	1019.0	3	0.5	61.5	59.9	62.7	8	8	6	4	X	X	32	2	2
8/10	39.1°N	125.3°W	0000	99	31	15	01	1	1018.3	7	1.0	64.2	62.2	62.8	2	2	6	4	0	0	34	2	2
8/10	38.9°N	124.4°W	0600	98	30	15	00	X	1016.6	8	0.5	59.2	57.4	56.2	X	X	X	X	X	X	XX	X	X
8/10	38.9°N	124.2°W	1200	99	33	18	02	0	1014.9	6	1.4	58.9	57.1	56.1	1	1	1	4	0	0	33	2	2
8/10	38.7°N	125.3°W	1900	99	31	16	02	0	1016.6	2	0.3	64.8	60.2	57.6	1	1	1	4	0	0	33	2	2
8/11	38.5°N	125.5°W	0000	99	34	20	03	0	1016.6	6	0.3	64.1	59.9	62.6	5	5	1	4	0	0	32	2	3
8/11	38.4°N	126.1°W	0600	99	33	22	02	1	1017.3	0	0.7	62.8	59.2	62.7	2	2	1	4	0	0	33	2	4

Table 5. -- Weather observations (USWB 1210-F), Hugh M. Smith cruise 40 (NEPAS)(cont'd)

Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
8/11	38.4°N	126.8°W	1300	99	02	16	02	0	1017.3	2	0.3	63.8	60.3	61.2	3	3	1	4	0	0	32	2	4
8/11	38.2°N	127.6°W	1800	99	36	12	02	0	1019.3	1	0.7	65.3	61.7	63.8	3	3	1	4	0	0	36	2	2
8/12	37.9°N	128.3°W	0000	99	34	15	02	0	1020.7	6	0.2	64.9	60.8	64.0	3	2	2	4	0	1	34	2	2
8/12	37.8°N	129.0°W	0600	99	33	15	02	0	1022.0	1	1.7	63.8	59.8	64.1	2	2	4	4	0	0	31	2	2
8/12	37.5°N	129.1°W	1200	99	34	15	02	1	1023.0	2	0.3	65.3	61.1	65.4	8	8	6	4	X	X	XX	X	X
8/12	37.4°N	129.7°W	1800	99	36	13	02	2	1024.4	1	0.2	65.0	59.9	65.1	8	8	5	3	X	X	36	2	0
8/13	37.1°N	128.9°W	0000	99	35	14	02	2	1023.4	7	1.0	66.4	62.0	64.3	8	8	5	3	X	X	36	2	0
8/13	37.2°N	128.5°W	0600	99	36	24	02	2	1024.0	2	1.0	64.3	60.0	64.2	8	8	6	4	X	X	XX	X	X
8/13	37.0°N	128.2°W	1300	99	35	17	02	2	1022.7	7	0.5	64.7	59.0	64.2	8	8	6	4	X	X	XX	X	X
8/13	37.1°N	127.6°W	1900	99	02	29	02	2	1022.7	0	0.3	64.4	60.4	63.8	8	8	6	4	X	X	36	2	2
8/14	37.0°N	127.1°W	0000	99	35	21	01	1	1021.0	7	1.4	63.7	60.3	63.4	1	1	1	4	0	0	36	2	3
8/14	36.9°N	126.6°W	0600	99	33	20	02	0	1020.3	1	0.3	62.9	60.8	63.4	1	1	1	4	0	0	XX	X	X
8/14	36.8°N	125.3°W	1300	99	32	20	02	1	1018.6	7	0.7	62.8	58.0	62.8	7	7	1	4	0	0	XX	X	X
8/14	37.0°N	125.6°W	1900	99	33	19	02	2	1019.3	0	0.0	63.1	59.6	62.6	6	6	1	4	0	0	01	2	4
8/15	37.1°N	125.2°W	0100	99	34	16	02	1	1016.6	7	1.4	62.8	59.5	60.3	0	0	0	9	0	0	35	2	3
8/15	38.5°N	125.9°W	0600	99	32	17	02	0	1017.6	0	0.3	61.1	59.2	59.8	0	0	0	9	0	0	XX	X	X
8/15	37.5°N	123.5°W	1200	98	32	23	00	X	1015.9	0	0.0	58.3	56.4	57.9	X	X	X	X	X	X	XX	X	X
8/27	36.8°N	122.4°W	0600	98	32	15	00	1	1020.3	1	0.7	58.1	56.3	59.4	X	X	X	X	X	X	XX	X	X
8/27	35.5°N	122.1°W	1200	98	32	18	00	0	1019.6	5	0.0	59.8	57.0	56.5	X	X	X	X	X	X	XX	X	X
8/27	35.4°N	123.0°W	1800	98	35	24	03	1	1022.0	2	1.7	61.5	58.2	58.2	6	0	0	9	7	1	35	3	3
8/28	35.0°N	123.4°W	0000	98	36	22	01	1	1020.7	7	1.7	64.8	60.6	62.5	1	1	4	3	0	0	34	3	3
8/28	34.5°N	124.5°W	0600	98	34	20	00	1	1021.0	3	0.5	63.8	59.7	64.0	X	X	X	X	X	X	XX	X	X
8/28	34.0°N	125.7°W	1300	98	34	20	00	X	1021.0	3	0.2	64.0	58.8	64.0	2	X	X	X	X	X	XX	X	X
8/28	33.6°N	126.5°W	1900	99	32	16	02	0	1021.3	0	0.3	68.3	61.8	66.1	2	2	2	3	X	X	32	2	2
8/29	33.2°N	128.0°W	0500	99	33	08	02	X	1020.3	1	0.7	66.1	61.3	66.3	X	X	X	X	X	X	XX	X	X
8/29	32.6°N	129.2°W	1300	99	31	07	00	X	1019.3	6	0.7	66.0	61.2	67.2	X	X	X	X	X	X	XX	X	X
8/29	32.3°N	129.9°W	1700	99	34	05	03	0	1020.0	2	0.7	69.0	63.0	68.3	2	2	4	4	0	0	34	2	0
8/30	32.0°N	131.0°W	0100	99	32	04	02	0	1019.0	6	0.7	71.5	64.0	71.0	1	1	4	4	0	0	01	2	0
8/30	31.9°N	131.7°W	0500	99	27	05	00	X	1020.3	3	1.0	70.5	64.0	71.1	X	X	X	X	X	X	XX	X	X
8/30	31.2°N	133.1°W	1300	98	27	14	00	1	1019.3	6	0.7	72.0	67.4	70.4	8	X	X	X	X	X	XX	X	X
8/30	30.9°N	133.8°W	1700	99	27	08	03	1	1021.0	2	1.2	72.0	67.6	70.2	4	2	2	5	3	1	34	3	0
8/31	30.5°N	135.0°W	0100	99	28	12	02	2	1021.0	6	0.3	74.3	69.0	71.1	7	2	2	5	7	0	32	3	2
8/31	30.6°N	135.5°W	0500	99	28	09	00	1	1021.0	3	0.9	72.5	68.0	71.4	X	X	X	X	X	X	32	3	1
8/31	29.9°N	136.5°W	1300	99	30	11	00	X	1021.7	6	0.3	71.1	67.0	71.2	X	X	X	X	X	X	XX	X	X
8/31	29.0°N	138.9°W	1800	99	28	08	03	0	1023.0	2	0.9	72.9	68.4	72.3	4	3	4	5	2	0	30	3	1
9/1	28.7°N	139.6°W	0600	97	33	07	21	6	1024.0	2	1.0	73.7	69.0	73.3	8	8	X	X	X	X	XX	X	X
9/1	28.1°N	141.0°W	1300	98	35	06	00	1	1022.4	7	0.7	73.4	69.4	73.7	X	X	X	X	X	X	XX	X	X
9/1	28.0°N	141.5°W	1800	99	03	07	03	1	1023.4	2	0.9	74.9	69.1	73.2	4	3	2	3	2	0	07	2	1
9/2	27.5°N	142.7°W	0100	99	05	10	02	1	1021.3	7	1.7	76.8	70.0	74.1	4	3	4	3	2	0	13	3	1
9/2	27.2°N	143.5°W	0600	99	05	10	00	1	1022.0	3	0.9	74.0	69.9	74.1	X	X	X	X	X	X	13	2	1
9/2	26.6°N	144.8°W	1300	99	10	08	00	2	1020.7	7	1.2	73.8	68.4	73.7	8	X	X	X	X	X	XX	X	X
9/2	26.5°N	145.0°W	1800	98	05	05	20	6	1021.7	1	1.4	74.0	69.3	73.4	6	4	2	3	1	4	15	2	3
9/3	26.0°N	146.4°W	0100	99	25	10	02	1	1019.3	7	1.4	75.0	69.3	75.4	5	4	2	3	1	4	10	2	3
9/3	25.7°N	147.2°W	0600	99	07	12	00	X	1020.0	3	1.0	73.8	69.9	74.2	X	X	X	X	X	X	XX	X	X
9/3	25.1°N	148.5°W	1300	98	10	13	00	X	1018.6	7	2.0	74.4	70.8	75.3	X	X	X	X	X	X	XX	X	X
9/3	24.8°N	149.0°W	1800	96	10	18	14	2	1019.3	2	0.9	73.8	71.3	75.5	8	7	7	3	0	1	14	4	3
9/4	24.4°N	150.1°W	0100	97	07	09	15	2	1017.6	7	1.4	77.5	71.9	76.6	7	5	9	3	2	1	13	4	2
9/4	24.0°N	151.8°W	0600	99	10	07	00	2	1019.0	3	1.4	75.5	71.6	76.0	6	X	X	X	X	X	13	4	2
9/4	23.7°N	151.7°W	1200	99	10	13	50	2	1017.6	7	1.7	72.7	71.0	75.9	X	X	X	X	X	X	13	4	2
9/4	23.4°N	152.6°W	1800	98	07	14	15	X	1018.0	2	0.9	76.5	73.0	76.7	6	4	4	4	0	4	07	3	2

Table 5.--Weather observations (USWB 1210-F), *Hugh M. Smith* cruise 40 (NEPAS)(cont'd)

					Wind		Weather		Pressure			Temperature			Clouds						Waves		
Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
9/4	23.1°N	153.5°W	2300	98	04	07	50	X	1016.9	7	1.7	77.0	73.3	76.8	8	6	4	4	0	4	07	3	2
9/5	22.6°N	154.5°W	0600	98	06	07	02	2	1016.6	3	1.0	77.9	72.4	76.8	7	6	X	X	X	X	06	2	0
9/5	22.3°N	155.3°W	1100	98	09	15	20	1	1015.9	8	1.2	76.4	72.4	76.9	2	X	X	X	X	X	XX	X	X
9/5	22.0°N	155.9°W	1500	98	09	16	00	X	1014.6	6	1.4	76.4	70.8	77.3	X	X	X	X	X	X	XX	X	X
9/5	21.7°N	156.5°W	1800	99	09	18	03	2	1015.9	2	1.0	77.8	72.9	76.8	8	1	1	3	0	4	09	2	2

Table 6.--Weather observations (USWB 1210-F), John R. Manning cruise 36 (NEPAS)[1]

Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
6/12	21.3°N	157.6°W	0600	99	06	18	02	0	1017.3	X	XX	77.2	72.0	76.5	2	2	2	5	0	0	06	2	4
6/12	22.4°N	156.5°W	1800	99	08	17	02	2	1019.6	2	1.0	77.0	70.2	76.5	6	4	4	4	0	0	09	3	3
6/12	22.7°N	156.0°W	2300	99	09	22	02	1	1020.3	0	0.0	80.0	72.0	76.5	2	2	1	5	5	0	09	2	3
6/13	23.2°N	155.8°W	0600	99	09	18	02	0	1020.7	3	1.4	78.0	72.0	76.5	2	1	1	5	5	0	09	3	3
6/13	23.8°N	155.3°W	1200	98	08	16	00	0	1021.0	0	1.0	76.7	72.0	76.0	8	8	5	4	X	X	09	3	3
6/13	24.3°N	154.7°W	1800	99	10	20	03	2	1021.7	2	0.7	76.3	72.0	76.0	6	6	5	5	1	8	09	3	5
6/13	24.8°N	154.2°W	2300	99	09	19	02	2	1021.7	4	0.0	79.0	74.0	76.5	7	7	1	5	1	8	09	3	5
6/14	25.3°N	153.7°W	0600	99	08	17	01	1	1022.0	2	1.0	76.0	71.5	76.0	3	3	5	5	7	1	09	3	4
6/14	25.8°N	153.2°W	1200	99	09	15	01	0	1022.4	7	0.9	75.1	70.0	75.5	5	5	5	5	7	1	09	3	4
6/14	26.5°N	152.5°W	1800	99	08	16	03	1	1022.7	2	1.0	76.5	71.0	75.0	3	3	4	5	X	X	11	3	3
6/14	27.0°N	152.1°W	2300	99	09	12	01	0	1022.4	0	0.7	76.5	71.0	75.5	2	2	4	5	5	1	09	3	3
6/15	27.4°N	151.6°W	0600	99	09	15	03	1	1021.7	2	XX	75.5	70.0	75.5	5	5	4	5	0	1	11	2	3
6/15	27.9°N	151.1°W	1200	98	07	11	02	1	1021.3	X	XX	74.0	70.0	75.2	3	3	2	3	0	0	07	2	2
6/15	28.4°N	150.5°W	1800	99	09	14	02	0	1021.0	1	0.5	76.0	70.5	75.0	2	2	4	5	5	4	09	2	2
6/15	29.2°N	149.9°W	2300	99	09	15	02	1	1020.7	0	0.0	76.0	69.0	75.0	5	5	4	5	5	1	09	2	3
6/16	29.7°N	149.2°W	0600	99	09	12	01	1	1020.3	2	0.9	74.5	68.0	74.0	1	1	4	5	4	1	09	2	2
6/16	30.2°N	148.5°W	1200	98	09	04	02	1	1019.6	7	1.0	72.0	66.0	73.2	6	6	2	4	0	0	09	2	1
6/16	30.9°N	148.0°W	1800	99	07	05	02	1	1021.7	2	1.9	73.8	67.0	73.3	2	0	0	9	1	0	09	2	2
6/16	31.4°N	147.4°W	2300	99	07	07	02	0	1022.4	2	0.5	75.0	68.0	74.5	1	1	5	5	1	0	07	2	2
6/17	32.0°N	146.7°W	0600	99	08	10	03	1	1022.7	2	1.0	74.0	68.0	73.8	7	4	1	5	2	4	07	2	2
6/17	32.6°N	146.2°W	1200	97	13	04	02	2	1024.0	2	0.7	71.0	68.2	70.4	7	0	0	9	1	5	06	3	2
6/17	33.1°N	145.7°W	1800	98	00	05	02	1	1025.7	2	0.9	71.8	69.5	69.3	6	0	0	9	4	0	16	3	2
6/17	33.9°N	145.1°W	2300	99	14	02	02	1	1025.7	8	0.7	73.0	67.1	73.0	6	3	1	3	1	8	00	2	2
6/18	34.3°N	144.4°W	0600	98	16	05	01	1	1025.7	0	1.0	72.0	67.0	70.3	3	2	1	3	2	1	49	2	2
6/18	35.0°N	143.9°W	1200	98	23	05	02	0	1025.7	8	1.0	69.8	67.1	69.0	3	3	2	3	0	0	49	2	2
6/18	35.6°N	143.3°W	1800	98	23	11	02	1	1024.7	4	0.0	67.1	66.2	67.0	5	5	4	3	1	4	30	2	2
6/18	36.0°N	143.0°W	2300	99	23	12	02	2	1024.4	7	0.7	69.3	67.0	66.3	7	7	5	3	1	0	24	3	3
6/19	36.2°N	143.0°W	0600	98	25	13	02	2	1023.0	0	0.0	66.6	64.5	65.5	8	8	6	3	X	X	25	3	3
6/19	36.2°N	143.0°W	1100	98	26	18	02	2	1022.7	7	0.7	65.5	63.5	65.5	8	8	6	3	X	X	27	2	2
6/19	36.3°N	142.7°W	1800	98	31	15	02	2	1023.7	2	1.0	66.0	64.0	65.5	8	8	6	3	X	X	30	3	3
6/19	36.7°N	141.9°W	2300	99	16	12	02	2	1024.7	7	0.3	60.0	59.0	63.9	7	7	6	4	0	0	16	4	5
6/20	36.9°N	141.8°W	0500	98	36	16	02	2	1025.7	2	1.0	62.0	58.5	63.6	8	8	6	4	X	X	35	2	2
6/20	36.9°N	141.8°W	1200	98	23	12	02	2	1026.1	0	0.0	62.5	56.0	63.0	8	8	5	3	X	X	33	3	3
6/20	37.4°N	141.0°W	2300	98	04	12	02	2	1026.8	2	0.7	63.0	56.0	63.8	8	8	5	3	X	X	02	3	2
6/21	38.0°N	140.1°W	0600	98	04	04	02	2	1026.4	2	0.7	62.0	55.5	63.0	8	8	5	3	X	X	02	3	2
6/21	38.6°N	139.4°W	1200	97	12	05	02	2	1025.1	7	0.7	59.9	53.7	62.0	8	8	5	3	X	X	05	3	2
6/21	38.9°N	139.2°W	1700	98	00	00	02	2	1025.7	2	0.3	60.0	54.0	62.0	8	8	5	3	X	X	01	2	2
6/21	39.3°N	138.6°W	2300	98	16	11	02	2	1024.7	7	1.7	62.5	57.5	61.5	8	8	5	3	X	X	35	2	2
6/22	39.7°N	138.2°W	0600	98	19	13	02	2	1023.4	0	0.0	61.1	56.2	61.0	7	7	5	3	0	0	19	2	2
6/22	39.7°N	138.2°W	1100	98	18	14	02	2	1021.7	7	1.0	61.0	56.3	61.5	8	8	5	3	X	X	20	2	2

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[1] All columns in USWB 1210-F are not included here. Those deleted are:

Column 2	Day of week	Column 23	Course of ship
" 3	Octant	" 24	Speed of ship
" 13	Barometer as read	" 31	Diff. sea-air, °F.
" 14	Barometer as corrected	" 32	Dew point, °F.
" 17	Air temperature, °F.		

Table 6.--Weather observations (USWB 1210-F), John R. Manning cruise 36 (NEPAS) (cont'd)

Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
6/22	39.8°N	138.0°W	1700	98	24	10	02	2	1022.0	2	0.7	63.0	58.5	61.5	8	8	5	3	X	X	25	1	3
6/22	40.8°N	136.5°W	2300	99	22	11	02	2	1022.0	7	0.7	65.7	60.2	60.4	7	7	5	3	0	0	22	1	2
6/23	40.9°N	136.5°W	0500	98	24	15	50	2	1022.7	2	1.0	60.0	59.0	60.0	8	8	5	3	X	X	24	3	3
6/23	41.3°N	135.6°W	1200	98	01	08	01	1	1024.0	2	1.0	59.0	55.5	59.5	2	2	1	3	0	0	23	3	2
6/23	42.0°N	135.0°W	1700	99	35	11	03	0	1026.1	2	1.7	59.1	53.0	59.5	4	4	5	3	0	0	35	4	4
6/23	40.6°N	135.1°W	2300	99	35	09	01	0	1027.8	2	0.9	60.0	54.0	61.5	2	2	5	4	6	0	34	3	3
6/24	40.6°N	135.1°W	0500	99	30	06	03	0	1027.8	2	0.7	60.5	55.0	61.0	4	4	4	5	1	0	34	3	4
6/24	39.8°N	135.0°W	1100	93	XX	11	00	0	1027.8	4	0.7	60.8	54.5	62.5	4	4	1	5	X	X	XX	X	X
6/24	39.1°N	135.0°W	1700	98	05	11	03	1	1028.1	2	0.3	60.5	55.0	63.5	8	8	4	3	X	X	09	3	2
6/24	39.3°N	135.0°W	2300	99	04	06	01	2	1026.8	7	0.9	64.0	59.0	62.5	5	5	4	3	0	0	35	2	2
6/25	40.0°N	135.0°W	0500	98	03	05	01	1	1025.7	6	1.0	59.8	55.0	63.0	3	2	1	3	0	1	30	2	1
6/25	39.9°N	134.9°W	1100	98	03	03	02	0	1024.0	7	1.0	61.0	56.5	62.5	3	3	1	3	0	1	02	2	1
6/25	39.8°N	134.8°W	1700	99	25	01	03	1	1024.4	2	0.2	62.0	57.0	62.5	5	5	4	5	0	0	04	3	1
6/25	38.9°N	134.8°W	2300	99	35	07	01	1	1024.0	0	0.0	66.8	59.8	65.8	4	4	1	5	0	0	09	3	1
6/26	38.5°N	134.5°W	0500	99	35	07	02	1	1024.0	5	0.3	64.0	59.0	64.8	5	5	1	5	0	0	35	2	2
6/26	38.5°N	134.5°W	1100	98	32	08	02	1	1023.7	7	0.3	63.0	58.2	64.0	6	5	1	5	0	0	32	2	2
6/26	38.2°N	134.3°W	2300	99	35	10	02	1	1024.7	0	0.0	67.0	62.0	65.5	2	2	1	5	0	0	01	3	2
6/27	36.9°N	133.9°W	0500	98	32	08	03	1	1024.4	5	0.3	65.0	63.0	65.5	7	7	4	5	X	X	35	3	2
6/27	36.9°N	133.9°W	1100	92	32	08	02	2	1022.7	X	XX	65.0	62.0	65.5	8	8	X	X	X	X	32	3	2
6/27	36.5°N	133.8°W	1700	98	32	08	03	2	1023.0	3	0.3	67.5	65.5	65.5	8	8	6	4	X	X	34	3	2
6/27	35.8°N	133.8°W	2300	98	35	19	02	2	1021.7	7	0.7	69.0	66.5	66.5	7	7	4	5	0	0	35	3	2
6/28	34.9°N	133.9°W	0500	91	34	13	45	4	1021.0	0	0.0	66.8	65.5	68.1	9	9	X	0	X	X	34	3	4
6/28	34.4°N	133.7°W	1100	98	34	14	01	2	1020.3	7	0.7	66.0	65.0	66.6	3	3	4	4	X	X	34	3	2
6/28	33.5°N	133.6°W	1700	98	35	23	21	5	1021.0	2	0.7	68.5	66.0	67.5	5	5	4	4	0	0	01	3	3
6/28	32.9°N	133.6°W	2300	96	20	15	03	2	1020.3	0	0.0	69.5	69.5	68.1	6	6	5	2	0	0	04	3	4
6/29	32.0°N	133.5°W	0500	98	04	25	20	2	1019.6	2	0.3	67.7	64.0	67.5	8	8	5	2	X	X	04	3	4
6/29	31.1°N	133.4°W	1100	98	07	14	02	2	1019.3	7	1.0	68.5	63.5	66.0	8	8	4	2	X	X	04	3	4
6/29	31.2°N	133.0°W	1700	98	05	19	02	2	1020.0	2	1.0	66.0	61.0	66.8	8	8	5	3	X	X	00	3	5
6/29	31.5°N	132.3°W	2300	98	05	18	02	2	1020.0	4	0.0	67.0	62.0	67.0	8	8	5	3	X	X	04	3	5
6/30	31.9°N	131.7°W	0500	98	05	18	02	2	1021.0	2	0.3	66.0	61.5	66.0	8	8	4	3	X	X	04	3	5
6/30	33.5°N	130.5°W	1100	98	05	18	02	2	1020.0	7	0.3	65.0	60.2	65.9	X	X	X	X	X	X	04	3	5
6/30	32.5°N	130.3°W	1700	98	05	18	02	2	1022.0	2	0.7	65.0	59.0	65.5	8	8	4	3	X	X	04	3	5
6/30	32.9°N	129.7°W	2300	98	01	18	02	2	1021.3	7	1.0	64.5	57.5	65.5	8	8	4	3	X	X	02	3	5
7/1	33.3°N	129.0°W	0500	97	33	15	02	2	1021.7	X	XX	64.5	59.5	64.2	8	8	8	3	X	X	35	4	5
7/1	33.7°N	128.2°W	1100	97	34	18	02	2	1021.0	X	XX	63.0	57.0	63.0	8	8	4	3	X	X	36	3	5
7/1	33.9°N	127.6°W	1700	98	35	18	02	2	1021.7	X	XX	63.0	58.5	62.5	6	6	4	3	0	0	35	3	4
7/1	34.2°N	126.9°W	2300	99	31	19	01	1	1020.7	7	0.7	64.2	61.3	63.5	3	3	8	3	0	9	02	3	4
7/2	34.5°N	126.4°W	0500	99	35	14	01	1	1020.7	4	0.0	63.5	58.5	63.3	3	3	8	3	X	X	35	3	2
7/2	34.5°N	126.4°W	1100	99	01	16	02	0	1017.6	7	0.2	62.0	58.5	63.5	3	3	8	3	0	0	00	3	2
7/2	34.6°N	126.2°W	1700	99	32	18	01	1	1021.0	3	1.0	62.5	58.0	62.5	4	4	1	4	0	0	01	3	2
7/2	34.8°N	125.6°W	2300	99	34	18	02	0	1021.0	7	0.3	65.5	59.0	61.5	3	3	2	4	0	0	01	3	2
7/3	35.0°N	125.3°W	0500	99	32	16	02	1	1020.0	0	0.0	61.5	59.0	61.5	3	3	2	3	0	0	31	3	6
7/3	41.3°N	126.1°W	1100	97	02	20	02	0	1021.0	2	0.7	61.5	57.8	61.6	3	3	2	3	0	0	35	3	6
7/3	35.0°N	127.1°W	1700	97	34	17	02	0	1023.7	2	1.4	64.0	59.5	62.5	3	3	4	3	0	0	01	3	4
7/3	34.9°N	127.9°W	2300	98	02	20	03	1	1024.4	7	0.2	65.0	61.0	64.0	7	7	4	3	0	0	00	3	4
7/4	35.0°N	128.9°W	0500	98	00	23	01	1	1023.7	4	0.0	63.0	59.0	63.1	5	5	5	4	0	0	00	3	6
7/4	34.9°N	129.8°W	1100	98	32	20	02	2	1023.0	4	0.0	64.0	58.0	64.5	7	7	5	4	X	X	01	3	4
7/4	34.9°N	130.6°W	1700	98	35	20	02	2	1024.4	2	1.0	64.0	58.5	64.5	4	4	4	4	9	0	01	3	4
7/4	35.1°N	131.5°W	2300	99	33	18	02	2	1023.0	3	1.7	64.5	60.2	64.4	7	7	5	5	6	0	01	4	5
7/5	35.1°N	132.5°W	0500	98	35	14	02	2	1023.7	0	0.0	64.0	58.5	65.5	8	8	4	3	X	X	02	3	5

Table 6.--Weather observations (USWB 1210-F), John R. Manning cruise 36 (NEPAS) (cont'd)

Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
7/5	35.6°N	131.8°W	1100	99	35	16	02	2	1022.2	1	1.7	63.5	59.0	65.0	8	8	4	3	X	X	01	3	4
7/5	36.0°N	131.1°W	1700	94	33	15	46	4	1022.4	2	0.3	63.5	61.0	64.0	8	8	5	3	6	X	30	3	4
7/5	36.3°N	130.6°W	2300	98	36	14	01	2	1021.3	7	0.2	64.0	61.0	64.5	5	5	5	3	0	0	01	3	3
7/6	36.6°N	130.2°W	0500	97	34	08	03	1	1021.7	2	0.3	62.5	61.0	63.0	6	4	6	0	4	X	32	3	3
7/6	36.6°N	130.2°W	1100	93	00	08	46	4	1021.3	0	0.0	62.4	60.5	63.5	9	9	X	0	X	X	00	2	2
7/6	36.8°N	130.0°W	1700	98	35	13	01	2	1023.4	2	1.0	62.7	60.0	63.0	6	6	4	3	6	X	35	2	2
7/6	37.2°N	129.3°W	2300	98	33	18	03	1	1023.0	7	0.7	64.0	61.0	63.5	8	6	4	3	X	X	35	3	3
7/7	37.4°N	129.1°W	0500	98	34	12	02	2	1022.7	2	0.7	63.5	59.3	63.0	8	8	5	2	X	X	34	3	2
7/7	37.5°N	129.0°W	1100	98	34	10	02	2	1022.7	7	0.7	62.5	58.5	63.0	4	4	5	2	X	X	34	2	2
7/7	37.5°N	129.0°W	1700	99	35	10	01	0	1023.7	2	0.5	64.5	61.0	63.0	2	2	1	3	0	0	00	2	2
7/7	37.7°N	128.5°W	2300	99	35	11	02	0	1023.0	7	0.7	64.5	61.0	62.0	0	0	0	9	0	0	02	3	3
7/8	38.1°N	128.0°W	0500	99	35	10	02	0	1023.0	3	0.7	62.5	57.0	62.0	0	0	0	9	0	0	00	3	3
7/8	38.6°N	127.5°W	1100	99	35	13	02	0	1021.7	7	0.7	63.5	60.0	61.5	0	0	0	9	0	0	00	3	3
7/8	38.8°N	127.0°W	1700	99	32	15	02	1	1022.4	2	0.2	63.3	60.0	61.9	8	8	5	3	X	X	00	3	3
7/8	39.4°N	126.3°W	2300	99	34	15	02	2	1021.3	X	XX	62.5	59.5	61.5	2	2	4	3	0	0	00	3	4
7/9	39.6°N	125.5°W	0500	99	35	18	02	0	1020.0	7	0.7	62.0	59.5	59.5	0	0	0	9	0	0	00	3	2
7/9	40.0°N	125.0°W	1100	98	00	14	02	0	1020.3	7	1.0	57.5	55.0	52.5	0	0	0	9	0	0	00	3	3
7/9	40.0°N	125.7°W	1700	98	33	12	02	1	1021.0	2	0.2	63.5	62.0	61.5	6	6	4	3	0	0	31	3	2
7/9	40.0°N	126.6°W	2300	99	33	09	02	1	1021.0	7	0.7	62.5	60.0	62.0	1	1	4	3	0	0	33	2	2
7/10	40.0°N	126.9°W	0500	98	31	08	02	0	1020.0	6	0.2	64.7	61.5	62.4	1	1	2	3	0	0	31	3	2
7/10	40.0°N	126.9°W	1100	98	24	08	02	0	1018.3	7	0.9	64.0	62.0	62.4	1	1	2	3	0	0	32	3	2
7/10	40.0°N	127.1°W	1700	97	30	12	03	1	1018.3	7	0.5	65.5	63.0	62.5	8	8	4	3	X	X	31	2	2
7/10	40.0°N	129.2°W	2300	99	28	15	01	2	1018.6	0	0.0	64.2	60.2	62.2	6	6	5	3	0	0	25	3	5
7/11	40.0°N	128.5°W	0500	98	28	15	02	2	1021.3	2	1.7	63.0	59.0	63.0	5	5	5	3	X	X	25	3	4
7/11	40.0°N	129.1°W	1100	98	34	13	02	2	1022.7	2	1.7	63.0	59.5	62.0	6	6	5	3	X	X	34	3	5
7/11	40.1°N	130.1°W	1700	99	05	06	02	2	1024.4	2	0.7	65.0	58.2	62.5	6	3	5	5	7	6	49	4	3
7/11	40.1°N	131.1°W	2400	99	10	07	02	2	1022.7	7	1.2	68.5	60.0	64.0	3	3	2	4	6	6	34	4	2
7/12	40.2°N	132.0°W	0500	99	15	10	02	1	1020.3	7	1.2	64.0	60.0	63.5	3	2	1	5	0	6	17	3	3
7/12	40.0°N	132.8°W	1100	98	14	20	00	1	1014.9	7	2.5	65.0	62.3	63.0	8	8	5	4	X	X	49	2	2
7/12	39.9°N	133.3°W	1700	97	24	10	21	6	1009.1	7	1.0	65.0	63.0	63.5	8	8	5	3	X	X	24	3	3
7/12	40.3°N	132.8°W	2300	98	18	13	02	6	1008.1	7	1.7	66.0	64.0	63.0	8	8	4	3	X	X	21	3	5
7/13	40.6°N	132.2°W	0500	98	24	11	03	1	1006.1	6	1.0	64.3	62.0	62.5	7	7	5	3	X	X	23	4	5
7/13	40.9°N	131.7°W	1100	98	24	16	02	2	1004.7	6	0.7	62.5	60.5	62.5	7	7	4	3	1	X	23	3	3
7/13	41.5°N	130.8°W	1700	99	25	05	02	1	1005.4	2	0.2	64.0	60.5	62.0	4	3	4	3	1	0	22	3	3
7/13	42.0°N	130.1°W	2300	99	24	14	02	1	1006.8	2	1.0	64.2	61.0	62.5	7	7	2	3	0	0	24	4	3
7/14	42.5°N	129.5°W	0500	98	30	18	03	1	1008.8	2	1.0	61.0	58.0	61.5	8	8	2	3	X	X	24	3	3
7/14	42.3°N	129.2°W	1100	98	27	20	01	1	1010.8	2	1.4	62.5	58.5	61.5	5	5	4	4	X	X	28	3	5
7/14	42.6°N	128.8°W	1700	99	29	17	01	2	1015.9	2	2.4	62.0	58.0	61.8	6	6	5	3	0	0	24	5	8
7/14	43.0°N	128.1°W	2300	98	29	21	02	2	1020.3	2	2.2	62.5	58.0	62.5	5	5	5	3	0	0	26	4	6
7/15	43.3°N	127.7°W	0500	98	28	06	02	2	1023.4	2	1.5	62.0	57.0	62.0	5	5	4	4	X	X	26	4	5
7/15	43.8°N	123.4°W	1100	98	29	16	02	1	1022.0	3	0.0	59.1	55.1	60.0	4	4	5	3	0	0	26	4	3
7/15	44.2°N	126.7°W	1700	99	33	14	02	1	1023.4	2	0.7	60.0	56.0	62.0	2	2	2	4	0	0	35	3	3
7/15	44.8°N	126.2°W	2300	99	33	12	02	1	1025.7	7	0.2	65.0	63.5	63.0	5	4	2	5	2	0	26	3	3
7/16	45.4°N	125.7°W	0500	98	34	13	02	1	1023.4	X	XX	61.5	58.0	62.0	4	4	2	4	0	0	02	2	3
7/16	45.8°N	124.8°W	1100	98	34	15	02	1	1022.4	7	0.5	60.0	55.0	62.5	4	4	2	4	0	0	01	2	3
7/22	46.0°N	124.5°W	2300	97	23	02	03	2	1017.3	X	XX	62.5	57.5	61.2	6	6	4	3	0	0	34	3	2
7/23	45.8°N	125.2°W	0500	97	33	01	02	2	1019.0	2	1.0	63.5	61.5	62.5	6	6	4	4	X	X	33	3	2
7/23	44.6°N	126.1°W	1100	98	34	09	50	1	1021.3	2	0.7	61.9	60.0	62.5	7	7	5	4	X	X	28	2	1
7/23	44.3°N	126.6°W	1700	97	34	08	21	2	1023.4	2	1.0	61.0	58.5	63.0	8	8	5	2	X	X	30	2	2
7/23	43.8°N	127.4°W	2300	98	32	11	01	2	1024.7	2	0.5	63.5	61.5	62.5	7	7	4	4	0	0	32	2	2

Table 6.--Weather observations (USWB 1210-F), John R. Manning cruise 36 (NEPAS) (cont'd)

Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
7/24	43.7°N	127.9°W	0500	98	34	09	02	1	1024.7	0	0.0	60.5	56.0	61.5	3	3	2	3	0	0	34	2	2
7/24	43.3°N	127.9°W	1100	98	32	15	02	0	1023.7	8	0.5	62.5	56.5	62.0	3	3	2	3	X	X	34	2	1
7/24	43.7°N	127.7°W	1700	98	33	12	03	1	1024.0	7	0.3	61.5	58.0	61.5	8	8	4	4	X	X	34	3	3
7/24	43.3°N	127.2°W	2300	99	33	12	02	1	1022.0	7	1.7	63.0	57.5	63.1	3	3	2	4	0	0	34	3	3
7/25	42.8°N	127.9°W	0500	99	33	14	02	0	1021.0	7	0.5	62.0	57.0	62.0	3	3	2	4	1	0	34	3	3
7/25	42.4°N	128.6°W	1100	99	27	13	02	0	1019.6	7	1.0	62.0	58.5	61.5	3	3	1	4	0	0	33	3	3
7/25	42.1°N	129.1°W	1700	99	32	15	03	1	1020.3	2	0.3	62.5	59.2	61.9	6	5	2	4	6	0	30	2	3
7/25	41.7°N	129.9°W	2300	98	32	21	03	2	1021.0	2	0.3	62.5	58.5	62.5	6	6	4	4	2	0	30	2	4
7/26	41.2°N	130.4°W	0500	98	30	21	03	2	1023.7	2	1.5	61.5	56.5	62.0	8	8	4	4	X	X	30	2	5
7/26	40.7°N	130.5°W	1100	97	00	18	02	2	1024.4	0	0.0	62.5	55.0	62.0	2	3	5	4	X	X	00	3	5
7/26	40.9°N	131.1°W	1700	97	00	21	02	2	1025.1	2	1.0	61.0	55.5	62.0	8	8	5	3	X	X	00	3	5
7/26	40.4°N	131.3°W	2300	98	33	18	02	1	1025.4	2	0.2	64.0	58.5	63.0	4	4	4	4	0	0	33	3	5
7/27	39.7°N	131.3°W	0500	98	00	16	01	2	1024.7	0	0.0	63.0	59.0	62.5	6	6	5	4	X	X	35	4	5
7/27	38.9°N	131.2°W	1100	98	00	14	02	2	1024.7	4	0.0	62.5	58.5	63.0	7	7	5	4	X	X	35	4	4
7/27	38.3°N	131.0°W	1700	98	30	17	21	2	1024.4	4	0.0	63.0	60.5	63.5	7	7	5	4	0	0	00	3	5
7/27	38.4°N	130.4°W	2300	98	31	11	01	2	1022.7	0	0.0	65.0	62.2	64.0	7	7	5	3	0	0	00	2	3
7/28	38.5°N	129.7°W	0500	98	03	16	02	2	1022.0	6	1.0	63.5	61.0	63.5	8	8	5	4	X	X	03	2	5
7/28	38.7°N	129.0°W	1100	98	33	18	01	1	1019.3	7	1.0	63.0	61.0	62.0	2	2	5	4	0	0	01	2	5
7/28	38.8°N	128.6°W	1700	92	33	16	50	2	1019.6	4	0.0	62.0	60.5	62.7	9	9	X	0	X	X	03	2	5
7/28	38.8°N	128.7°W	2300	98	35	16	01	2	1019.0	0	0.3	63.0	60.5	63.0	5	5	2	4	2	0	32	2	3
7/29	38.7°N	127.6°W	0400	98	31	15	01	2	1018.3	7	0.3	64.5	61.0	62.5	2	2	4	5	0	0	30	2	2
7/29	38.8°N	128.7°W	1100	98	26	06	00	1	1016.9	7	1.0	64.0	62.5	62.5	4	4	4	5	X	X	32	2	2
7/29	38.8°N	128.6°W	1700	98	28	04	02	1	1017.3	4	0.0	65.0	62.0	63.0	3	3	4	4	5	0	32	2	2
7/29	38.9°N	127.8°W	2300	98	34	11	03	1	1017.3	4	0.0	65.0	62.0	63.5	5	5	4	5	0	0	01	2	2
7/30	39.0°N	127.5°W	0500	98	33	12	02	2	1017.6	2	0.7	64.7	61.5	63.2	7	7	8	3	X	X	29	2	2
7/30	39.0°N	127.5°W	1100	97	34	17	02	2	1018.6	2	0.2	63.0	58.0	62.8	7	7	8	3	X	X	30	2	2
7/30	39.0°N	127.6°W	1700	98	01	12	02	2	1020.7	2	1.0	63.5	58.0	62.6	8	8	5	3	X	X	32	2	2
7/30	39.0°N	127.5°W	2400	99	32	12	02	2	1020.3	0	0.0	63.0	58.0	62.8	6	6	5	4	0	0	32	2	3
7/31	39.0°N	127.5°W	0500	99	34	20	02	1	1020.3	4	0.0	62.0	57.5	62.2	2	2	5	4	X	X	34	2	3
7/31	39.0°N	127.4°W	1200	98	33	16	02	0	1020.0	7	0.3	62.5	59.0	62.0	3	3	4	5	0	0	32	2	2
7/31	39.0°N	127.4°W	2300	98	33	12	02	0	1021.7	2	0.3	65.0	60.0	63.0	2	2	4	5	0	0	33	2	2
8/1	39.0°N	127.6°W	1700	98	35	30	02	1	1022.4	2	0.7	62.5	58.5	62.6	2	2	4	4	0	0	35	3	6
8/1	39.2°N	127.6°W	2300	98	35	20	02	1	1021.0	7	0.7	64.0	59.5	62.5	3	3	4	5	0	0	35	3	7
8/2	39.3°N	127.5°W	0500	98	00	25	02	0	1021.7	2	0.2	62.5	58.0	62.3	3	3	4	5	X	X	50	2	0
8/2	39.5°N	127.5°W	1100	98	00	28	02	0	1020.7	7	0.5	61.3	58.0	62.8	4	4	4	5	X	X	00	2	7
8/2	39.5°N	127.5°W	1700	98	00	22	02	0	1021.0	2	0.3	64.0	60.0	62.5	3	3	3	5	0	0	00	2	7
8/2	39.3°N	127.5°W	2300	99	34	19	03	1	1020.3	6	0.7	64.0	60.1	62.0	6	6	5	4	0	0	00	2	7
8/3	38.5°N	127.5°W	0500	99	35	20	02	2	1019.6	6	0.3	63.0	59.5	62.5	5	5	5	4	0	0	00	2	5
8/3	38.8°N	127.6°W	1300	98	34	20	03	1	1011.9	7	1.0	64.0	60.5	62.5	8	8	4	4	X	X	03	2	3
8/3	39.0°N	127.6°W	1700	97	28	09	46	2	1017.3	7	0.3	64.8	61.8	59.8	8	3	5	6	0	8	31	2	2
8/3	38.8°N	127.1°W	2300	98	29	09	02	1	1016.3	0	0.0	64.0	60.5	59.8	3	3	5	4	4	0	30	2	2
8/4	38.9°N	126.5°W	0500	98	30	11	03	1	1015.9	7	0.3	62.0	60.0	61.3	7	7	4	4	X	X	30	2	2
8/4	38.9°N	126.5°W	1100	92	30	09	02	2	1014.2	7	0.0	61.2	59.0	60.8	8	8	X	0	X	X	30	2	2
8/4	38.8°N	125.7°W	1700	98	23	06	02	1	1015.2	0	0.0	63.0	60.5	61.8	1	1	4	5	0	0	27	2	2
8/4	39.0°N	126.2°W	2300	99	25	11	03	0	1015.6	7	0.3	64.0	61.0	61.3	2	2	2	4	6	9	29	4	8
8/5	38.8°N	126.5°W	0500	99	27	06	02	0	1015.9	2	0.2	63.0	60.5	60.5	2	X	X	X	X	X	30	4	7
8/5	38.5°N	126.1°W	1100	99	27	11	02	0	1015.2	7	0.3	62.5	59.5	61.5	1	1	0	6	6	0	30	3	4
8/5	38.4°N	125.8°W	1700	98	31	04	03	1	1017.3	2	1.5	61.0	58.5	55.7	7	7	4	4	0	0	31	4	4
8/5	38.3°N	125.7°W	2300	99	27	09	02	1	1017.6	0	0.0	63.0	59.5	56.5	1	1	5	4	0	0	30	4	5
8/6	38.1°N	125.7°W	0500	98	25	11	03	1	1018.3	2	0.3	60.5	58.0	56.8	6	6	5	4	6	1	30	3	4

Table 6.--Weather observations (USWB 1210-F), John R. Manning cruise 36 (NEPAS) (cont'd)

					Wind		Weather		Pressure			Temperature			Clouds						Waves		
Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
8/6	37.8°N	125.7°W	1200	98	31	11	01	1	1017.6	7	0.3	62.3	60.0	60.0	3	3	4	4	0	0	30	3	2
8/6	37.1°N	125.1°W	1700	99	33	09	01	2	1018.6	2	1.0	63.0	60.2	60.9	7	7	5	3	0	0	35	2	2
8/6	36.8°N	124.6°W	2300	99	30	06	02	1	1018.6	4	0.0	64.0	60.0	60.1	1	1	4	4	0	0	35	3	2
8/7	36.8°N	124.6°W	0400	99	30	12	02	0	1017.6	7	0.2	61.7	60.0	59.0	0	0	0	9	0	0	35	3	3
8/7	36.8°N	124.6°W	1100	90	32	11	45	2	1016.9	7	0.3	60.0	60.0	59.0	9	9	X	0	X	X	32	2	2
8/7	36.6°N	124.3°W	1800	95	26	06	28	2	1019.0	2	1.9	64.0	63.0	60.5	8	8	4	3	X	X	30	2	2
8/7	36.1°N	123.5°W	2300	97	30	04	03	1	1018.3	7	0.3	64.5	62.0	62.0	7	7	4	3	0	0	30	3	2
8/8	36.3°N	123.8°W	0500	97	30	10	40	2	1018.0	2	0.7	63.0	60.1	60.2	8	8	5	3	X	X	30	3	2
8/8	36.1°N	123.5°W	1100	97	30	08	02	2	1018.0	4	0.0	62.0	59.5	60.2	8	8	5	3	X	X	30	2	2
8/8	36.2°N	123.4°W	1700	97	31	12	02	2	1018.6	2	1.0	62.5	59.5	60.5	8	8	4	3	X	X	30	2	2
8/8	35.3°N	123.4°W	2300	99	32	11	02	1	1018.0	7	0.5	64.8	61.0	61.5	5	3	5	4	6	0	32	2	2
8/9	34.8°N	123.4°W	0500	99	31	18	02	1	1016.9	7	0.5	62.5	59.5	61.7	1	1	5	5	0	0	30	2	2
8/9	34.8°N	123.4°W	1100	99	30	17	02	0	1016.3	7	0.3	62.5	60.0	61.5	3	3	1	4	0	0	30	2	2
8/9	34.8°N	123.8°W	1700	99	32	13	03	1	1017.3	2	0.3	63.0	60.0	61.0	3	2	2	4	0	2	32	3	3
8/9	34.8°N	124.2°W	2300	99	32	20	02	0	1016.3	7	0.5	64.2	60.5	63.0	1	1	2	4	0	0	30	3	4
8/10	34.7°N	124.5°W	0500	97	32	21	03	1	1015.9	5	1.5	63.5	62.3	62.5	8	8	4	4	X	X	30	3	4
8/10	34.5°N	125.1°W	1100	98	34	22	02	2	1015.6	7	0.7	62.0	59.5	62.5	8	8	5	4	X	X	34	3	4
8/10	34.3°N	126.0°W	1700	99	34	20	02	1	1017.6	2	1.0	70.0	60.5	63.8	3	3	2	4	0	0	35	3	4
8/10	34.2°N	126.8°W	2300	99	00	19	02	1	1017.3	7	0.7	66.5	61.0	65.5	5	2	4	4	5	0	01	3	3
8/11	34.0°N	127.6°W	0500	98	01	17	02	1	1017.3	2	0.9	65.0	61.2	65.0	7	7	2	3	X	X	01	3	4
8/11	34.0°N	128.4°W	1100	98	00	17	02	2	1017.3	4	0.0	65.0	61.0	65.5	4	4	2	4	X	X	00	3	4
8/11	33.7°N	129.2°W	1700	98	02	21	02	2	1019.6	2	1.2	67.5	63.0	66.0	8	8	4	4	X	X	00	3	4
8/11	33.6°N	130.0°W	2300	99	00	12	02	2	1020.0	4	0.0	68.0	63.2	66.6	7	7	5	4	0	0	00	3	3
8/12	33.3°N	130.0°W	0500	98	00	12	02	1	1021.0	2	0.5	67.5	63.2	67.5	5	5	5	4	X	X	00	3	3
8/12	33.1°N	131.6°W	1100	98	00	12	02	2	1020.7	7	0.2	67.5	64.0	68.0	6	6	5	4	X	X	00	3	2
8/12	33.0°N	132.5°W	1700	99	04	16	02	2	1022.4	2	0.9	68.5	64.0	68.2	8	8	5	4	X	X	04	2	2
8/12	32.7°N	133.0°W	2300	99	04	12	02	2	1022.0	7	0.7	69.0	62.7	69.0	5	5	4	4	0	0	06	2	3
8/13	32.3°N	134.0°W	0500	99	04	12	02	1	1023.4	3	1.0	69.5	64.0	68.7	2	2	1	4	0	0	05	2	2
8/13	31.9°N	134.8°W	1100	98	05	13	02	1	1022.7	4	0.0	68.5	63.5	69.0	8	8	4	4	X	X	05	2	2
8/13	31.7°N	135.5°W	1700	98	04	14	03	2	1023.7	2	0.5	70.0	62.0	69.8	7	7	4	3	0	0	04	2	2
8/13	31.4°N	136.6°W	2300	99	04	13	01	1	1022.7	7	0.3	71.5	66.0	70.3	3	1	1	3	4	0	03	2	2
8/14	31.0°N	137.5°W	0500	98	05	14	02	1	1023.0	2	0.7	70.2	63.1	69.2	6	4	2	3	6	1	04	3	3
8/14	30.6°N	138.4°W	1100	98	04	17	02	1	1022.0	7	1.0	69.8	62.6	69.8	5	5	2	3	4	0	04	3	3
8/14	30.2°N	139.3°W	1800	98	04	09	02	1	1022.7	2	0.3	72.0	64.5	70.7	6	4	4	4	1	8	01	3	3
8/14	29.9°N	139.9°W	2300	99	04	09	02	1	1021.3	7	0.7	74.3	65.5	71.6	6	3	2	3	8	0	04	3	3
8/15	29.5°N	140.9°W	0500	99	04	10	02	1	1020.7	5	0.3	71.0	64.0	72.5	6	6	2	3	4	1	04	3	3
8/15	29.0°N	141.1°W	1200	99	07	13	02	1	1019.6	7	0.7	69.7	64.0	71.5	5	4	4	4	4	0	04	3	3
8/15	28.7°N	142.4°W	1800	99	07	19	02	1	1020.3	1	0.7	72.5	65.5	72.2	5	4	2	4	6	0	08	3	3
8/15	28.3°N	143.3°W	2300	98	02	16	02	1	1019.3	7	0.5	73.0	66.0	73.5	6	6	2	3	6	0	12	3	3
8/16	28.0°N	144.0°W	0500	98	09	17	02	1	1019.3	4	0.0	72.5	67.5	73.5	4	3	4	4	4	8	10	3	3
8/16	27.6°N	144.9°W	1100	98	08	13	03	0	1019.6	7	0.2	71.2	67.0	74.8	3	3	2	4	0	0	34	3	3
8/16	26.9°N	145.6°W	1800	98	08	14	02	0	1021.0	2	0.7	73.0	67.5	73.0	4	4	2	4	0	0	32	3	3
8/16	26.6°N	146.3°W	2300	98	07	12	02	0	1020.0	7	0.9	74.5	68.0	73.5	2	1	1	4	1	1	10	3	3
8/17	26.3°N	147.0°W	0500	98	10	14	02	1	1020.0	4	0.0	73.5	69.2	74.6	6	6	2	3	X	X	10	3	3
8/17	25.8°N	148.0°W	1100	98	09	12	02	2	1020.3	4	0.0	73.5	67.0	74.0	5	5	2	3	X	X	09	3	3
8/17	25.5°N	148.7°W	1700	98	07	16	02	2	1021.7	2	0.7	75.3	68.0	74.3	5	4	4	4	2	0	07	3	4
8/17	25.2°N	149.6°W	2300	99	07	17	02	2	1021.7	6	1.0	78.8	71.0	75.4	6	5	2	3	6	0	08	2	3
8/18	24.8°N	150.4°W	0500	98	08	20	02	2	1021.0	5	0.0	74.5	70.0	75.0	6	6	2	3	6	0	08	3	3
8/18	24.4°N	151.4°W	1100	99	07	17	01	1	1020.7	7	0.9	74.5	70.5	75.0	3	3	1	5	0	0	07	3	3
8/18	24.0°N	152.1°W	1700	99	07	15	02	1	1020.3	2	0.9	75.8	71.0	75.9	6	6	2	3	0	2	07	3	3

Table 6.--Weather observations (USWB 1210-F), John R. Manning cruise 36 (NEPAS) (cont'd)

Date, 1957	Latitude	Longitude	Time, GCT	Visibility	Wind		Weather		Pressure			Temperature			Clouds						Waves		
					Direction	Speed, kt.	Present	Past	Bar. corr., mb.	Characteristic	Amt. change	Dry bulb, °F.	Wet bulb, °F.	Sea water, °F.	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
8/18	23.7°N	152.9°W	2300	99	07	18	02	1	1019.0	7	1.4	78.2	72.8	77.5	4	4	2	3	0	0	07	3	3
8/19	23.2°N	153.6°W	0500	98	07	21	15	1	1018.3	5	0.2	76.5	72.0	76.0	6	5	4	4	X	X	07	3	4
8/19	22.9°N	154.4°W	1100	98	07	18	02	1	1018.0	7	1.0	75.5	72.2	77.0	3	3	2	3	0	0	07	3	4
8/19	22.5°N	155.4°W	1800	98	07	21	02	0	1017.6	2	0.2	78.4	71.5	77.0	3	3	2	3	0	0	07	3	4
8/19	22.1°N	156.1°W	2300	97	07	23	03	1	1017.6	4	0.0	77.5	73.0	78.0	6	5	4	4	1	0	07	3	4
8/20	21.7°N	156.8°W	0500	98	09	19	03	1	1016.3	X	XX	78.0	73.0	77.4	7	5	2	3	6	2	10	3	5

Table 7.--Summary of observations made at the submarine photometer station, John R. Manning cruise 36 (NEPAS) June 11 - August 20, 1957

			Position		Photometer													
Station	Date 1957	Time	Latitude north	Longitude west	50% level (m.)	Incident light ft.-c.	10% level (m.)	Incident light ft.-c.	5% level (m.)	Incident light ft.-c.	1% level (m.)	Incident light ft.-c.	Secchi disc depth (m.)	Forel color	Cloud cover1/	Cloud type1/	Sea1/	Remarks
1	6/12	1340	22°43'	156°07'	-	5250	53.5	-	89.0	-	141.0	-	44	3	6	3	4	+10 zone time, boat rolling
2	6/14	1340	26°55'	152°08'	-	11,250	-	-	-	-	-	-	32	1	2	1,6,8	3	Photometer readings not recorded
3	6/15	1340	29°11'	149°52'	3.5	7200	41.0	-	77.5 (74.8)2/	-	129.0 (124.6)	-	28	2	3	1,6,8	1	-
4	6/16	1340	31°27'	147°20'	-	9000	-	-	-	-	-	-	42	2	1	1,5	2	Cable broke
6	6/17	1440	33°52'	145°01'	11.0	9750	24.0	-	71.0 (69.9)	-	105.5 (103.9)	-	48	2	3	2,5,8	2	+9 zone time, 50% and 10% not reliable
8	6/18	1440	36°00'	143°00'	11.0	5640	42.0	2250	64.0	2250	112.0	5640	32	2	8	5,6	2	-
10	6/19	1440	36°42'	141°56'	2.0	5610	41.0	5610	66.0 (65.0)	9000	116.0 (114.2)	9000	28	2	7	6	5	-
12	6/20	1440	37°22'	140°59'	3.0	5610	35.0	-	72.0	-	132.0	-	30	2	7	0,6	2	-
13A	6/21	1440	39°18'	138°39'	3.5	3900	29.0	-	49.0	-	104.0 (102.4)	-	28	2	8	6	1	-
14	6/22	0730	39°43'	138°02'	1.5	1440	31.5	-	67.5	-	111.0 (110.5)	-	28	2	8	6	3	1% not reliable
15	6/22	1440	40°23'	137°08'	10.0	7500	28.5	-	46.0 (45.8)	-	83.0 (78.0)	-	24	3	7	6	2	7,500 is an average of 7,800 and 7,200
17	6/23	1440	41°10'	135°04'	2.0	7800	33.0 (32.9)	-	49.0 (48.8)	-	102.0 (101.6)	-	36	2	2	6	3	Boat rolling
19	6/24	1540	39°20'	134°57'	2.0	6900	45.0	7200	72.0 (71.7)	7200	149.0 (148.4)	7200	30	2	6	6	2	+8 zone time
21	6/25	0800	39°48'	134°53'	5.0	5250	47.0	7200	61.0	5700	-	-	42	1.5	2	6	1	Cable broke
22	6/25	1530	38°55'	134°50'	10.0	7800	-	-	-	-	-	-	48	2	4	8	1	Cable broke
24A	6/26	0800	38°24'	134°26'	2.0	3750	-	-	-	-	-	-	36	1.5	6	6,8	2	Cable broke

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1/ Coded according to U. S. N. H. O. Pub. 606-c (1956).

2/ Brackets enclose values corrected for wire angles.

Table 7.--Summary of observations made at the submarine photometer station, John R. Manning cruise 36 (NEPAS) June 11 - August 20, 1957 (cont'd)

			Position		Photometer													
Station	Date 1957	Time	Latitude north	Longitude west	50% level (m.)	Incident light ft. -c.	10% level (m.)	Incident light ft. -c.	5% level (m.)	Incident light ft. -c.	1% level (m.)	Incident light ft. -c.	Secchi disc depth (m.)	Forel color	Cloud cover[1]	Cloud type[1]	Sea[1]	Remarks
24A	6/26	1540	37°36'	134°00'	-	-	-	-	-	-	-	-	40	2	2	6,8	2	Cable broke
-	6/27	0800	36°31'	133°48'	-	-	-	-	-	-	-	-	28	2	6	8	2	Cable broke
25	6/27	1540	35°48'	133°46'	8.0	4200	-	4200	-	5400	-	5400	34	2	7	6	2	10%, 5%, and 1% not reliable
27	6/28	1540	32°38'	133°32'	-	-	45.0 (44.8)	10,800	69.0 (66.6)	11,150	-	3750	38	2	6	6	4	Secchi disc 60° angle boat rolling
29	6/29	1540	31°33'	132°16'	4.5	3900	44.0 (43.3)	5100	77.0 (76.6)	3750	-	6000	-	-	8	6	5	Rough sea, intermittent cloudiness
31	6/30	1540	32°54'	129°38'	4.0	3750	49.0	3450	70.0 (68.9)	3450	-	2400	30	2	8	6	5	-
33	7/1	1540	34°14'	126°47'	6.0	3450	30.0	3900	51.0	3450	72.0 (71.7)	3900	28	2	6	1,6,8	4	Intermittent cloudiness
35	7/2	0940	34°35'	126°08'	1.0	9750	22.5	10,500	50.0	9750	85.0 (83.7)	10,500	28	2	4	6,8	3	-
36	7/2	1540	34°49'	125°32'	12.0	10,650	24.5	9750	39.5	7500	90.0 (86.9)	7800	24	4	3	6,8	3	-
38	7/3	1540	34°56'	127°58'	2.5	3600	37.5 (37.2)	3294	76.0 (73.4)	2100	-	3294	-	-	7	6	4	-
40	7/4	1540	35°05'	127°36'	-	-	28.0	1200	88.0 (86.7)	1350	-	1440	22	2	7	4,6	5	Rain
42	7/5	1545	36°23'	130°32'	3.0	3600	47.0 (46.3)	11,250	72.0 (69.5)	3900	-	3900	36	2	5	6,8	4	Fog patches
44	7/6	0940	36°50'	129°59'	7.0	3750	31.0	7800	72.0	3750	-	4686	30	2	5	8	2	-
45	7/6	1540	37°09'	129°26'	3.0	2835	41.5	2376	89.5	1920	-	1920	34	2	8	6	4	-
46	7/7	0950	37°27'	129°02'	2.0	11,250	41.0	11,250	60.6	11,250	-	11,250	34	2	3	8	3	Boat rolling
47	7/7	1540	37°47'	128°31'	5.0	7500	32.0	9375	54.0	9375	-	9375	-	-	0	X	3	-
48A	7/8	1540	39°22'	126°16'	8.0	7500	32.0 (31.9)	7800	57.0 (56.1)	7650	-	7500	-	-	2	6	3	-
49A	7/9	1540	39°59'	126°38'	7.5	9375	31.0	8436	52.0	7500	-	8436	32	2	1	6	3	-

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[1] Coded according to U.S.N.H.O. Pub. 606-c (1956).

Table 7. --Summary of observations made at the submarine photometer station, John R. Manning cruise 36 (NEPAS) June 11 - August 20, 1957 (cont'd)

			Position		Photometer													
Station	Date 1957	Time	Latitude north	Longitude west	50% level (m.)	Incident light ft. -c.	10% level (m.)	Incident light ft. -c.	5% level (m.)	Incident light ft. -c.	1% level (m.)	Incident light ft. -c.	Secchi disc depth (m.)	Forel color	Cloud cover1/	Cloud type1/	Sea1/	Remarks
51	7/10	0940	40°02'	127°07'	0.5	2835	64.0	1920	67.0 (66.7)	1920	-	2376	32	2	8	6	3	-
53	7/11	1540	40°07'	131°06'	-	-	-	-	58.0	9365	-	9365	36	2	3	1,4,5	2	-
55	7/12	1540	40°16'	132°42'	-	1560	45.0 (44.8)	1560	85.0 (82.1)	1200	-	1680	30	2	8	6	4	Rain and fog, rolling
57	7/13	1540	41°58'	129°57'	0	2835	27.0 (25.9)	2835	52.0 (51.8)	2835	-	2376	28	3	6	6,8	3	-
59	7/14	1540	43°03'	128°09'	6.0	4686	22.0	5622	41.0 (40.8)	7500	-	7500	28	3	5	6,8	5	-
61	7/15	1540	44°50'	126°11'	1.2	2835	16.0	7500	31.0 (30.9)	7500	-	6564	22	5	5	4,5,8	3	Intermittent sunshine
64	7/23	0940	44°18'	126°38'	0.6	2915	16.5	3294	35.5	3294	-	3522	20	6	9	6	2	-
65	7/23	1540	43°51'	127°22'	5.0	5625	30.0	4686	50.0	5625	-	4686	32	3	6	6	3	-
66	7/24	0800	43°43'	127°51'	-	-	30.0	2835	68.0	2835	-	2835	32	3	5	4,6,8	2	-
67	7/24	1540	43°13'	127°12'	4.0	7500	23.0	7500	41.0	7500	-	7500	26	4	3	8	3	-
69	7/25	0940	42°05'	129°12'	-	-	12.0	7500	40.0	7500	-	7500	24	3	6	4,6,8	3	-
70	7/25	1540	41°37'	129°54'	4.5	7500	34.0	7500	53.0 (52.2)	4696	-	-	28	2.5	6	6,8	4	-
72	7/26	0940	40°52'	131°09'	-	11,250	40.0	2529	74.5 (72.0)	2835	-	3750	28	2	8	6	5	-
73	7/26	1540	40°23'	131°19'	2.0	3750	32.0	3294	70.0 (63.4)	6000	-	6000	24	3	3	6,8	5	-
75	7/27	0940	38°18'	130°53'	1.0	2376	24.0	3750	70.8 (69.7)	3750	-	9375	28	2	7	6	5	-
77	7/27	1550	38°26'	130°17'	4.0	11,250	40.0	3750	66.0 (65.0)	3750	-	3750	30	2	6	6	3	-
79	7/28	0940	38°46'	128°37'	0	1920	37.0 (36.8)	1440	74.5 (72.0)	1920	-	1920	30	2	6	6	3	-
80	7/28	1540	38°39'	128°40'	2.0	1920	43.0	1920	75.0 (73.9)	2835	-	6000	30	2	8	5	4	-

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1/ Coded according to U.S.N.H.O. Pub. 606-c (1956).

Table 7.--Summary of observations made at the submarine photometer station, John R. Manning cruise 36 (NEPAS) June 11 - August 20, 1957 (cont'd)

			Position		Photometer													
Station	Date 1957	Time	Latitude north	Longitude west	50% level (m.)	Incident light ft. -c.	10% level (m.)	Incident light ft. -c.	5% level (m.)	Incident light ft. -c.	1% level (m.)	Incident light ft. -c.	Secchi disc depth (m.)	Forel color	Cloud cover[1]	Cloud type[1]	Sea[1]	Remarks
81	7/29	0900	38°46'	128°36'	-	-	32.0	7500	56.0	7500	-	7500	34	2	7	8	2	-
82	7/29	1540	38°56'	127°51'	5.0	6000	27.0	6000	54.0	6000	-	6000	28	2.5	6	6	3	-
83	7/30	1640	39°01'	126°26'	2.0	3750	31.0	3750	62.0	3750	-	3750	28	3	6	6	3	-
83[3]	7/31	1550	38°58'	127°28'	5.0	7500	30.0	7500	53.0 (52.8)	7500	-	7500	26	3	3	6,8	3	-
85	8/3	0940	38°56'	127°11'	-	7500	-	7500	37.0 (36.8)	11,250	-	7500	24	4	7	2,6	2	-
86	8/3	1540	38°53'	127°04'	8.0	7500	25.0	7500	40.0	7500	-	9366	24	5	3	2,6	3	50% not reliable
88	8/4	0940	38°56'	125°42'	-	7500	-	9366	46.0	9366	-	9366	26	3.5	1	8	2	-
89	8/4	1540	38°57'	126°10'	6.0	7500	25.0	7500	45.0	7500	-	7500	24	4	3	3,4,6,8	6	-
91	8/5	0940	38°14'	125°40'	-	7500	21.0	3291	55.5	2376	-	2376	20	5	7	6	4	-
92	8/5	1215	38°05'	125°25'	8.0	9366	17.0	9366	22.7	9366	68.0 (67.0)	9366	16	5	2	6	5	-
93	8/5	1540	38°14'	125°44'	5.0	7500	24.0	7500	34.0	7500	-	7500	22	4	1	6	5	-
95	8/6	0940	37°06'	125°07'	-	7500	-	9366	30.0	9366	-	9366	24	4	4	6	2	-
96	8/6	1210	36°58'	124°56'	3.0	3750	16.0	3750	41.0	3750	-	3750	18	5	7	6	2	-
98	8/6	1540	36°45'	124°34'	4.0	7500	15.0	7500	26.0	7500	-	7500	20	5	1	6	2	-
100	8/7	0950	36°35'	124°17'	-	7500	11.0	6561	32.0	5625	-	7500	-	-	8	6	2	Fog thin
101	8/7	1540	36°45'	124°34'	5.0	5625	19.0	5625	35.0	5625	-	5625	22	4	6	6	2	-
102	8/8	0815	36°08'	123°24'	-	1920	20.0	1920	40.0	1920	-	1920	20	4	8	6	2	-
103	8/8	1540	35°19'	123°23'	-	3750	8.0	3750	17.0	3750	-	3750	10	5	6	6	2	-
104	8/9	0940	34°47'	123°42'	-	9375	-	9375	14.5	9375	-	9375	14	5	2	1,6	3	-
105	8/9	1555	34°49'	124°10'	5.0	7500	22.0 (21.9)	7500	36.0 (35.9)	7500	-	7500	22	3	1	8	4	-
107	8/10	0940	34°17'	126°05'	-	9375	-	9375	55.0	9375	-	7500	30	2.5	8	6	4	-
108	8/10	1540	34°12'	126°52'	2.0	2376	38.0	3750	62.0	5625	-	4696	32	2	6	4,6,8	4	50% not reliable

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[1] Coded according to U. S. N. H. O. Pub. 606-c (1956).

[3] 24-hour gill-net station.

Table 7.--Summary of observations made at the submarine photometer station, John R. Manning cruise 36 (NEPAS) June 11 - August 20, 1957 (cont'd)

			Position		Photometer													
Station	Date 1957	Time	Latitude north	Longitude west	50% level (m.)	Incident light ft.-c.	10% level (m.)	Incident light ft.-c.	5% level (m.)	Incident light ft.-c.	1% level (m.)	Incident light ft.-c.	Secchi disc depth (m.)	Forel color	Cloud cover 1/	Cloud type 1/	Sea 1/	Remarks
110	8/11	0940	33°41'	129°14'	1.0	3750	47.0 (46.8)	3750	88.0 (86.7)	4696	-	4696	30	2	8	6,8	4	50% not reliable
111	8/11	1540	33°33'	130°03'	6.0	5625	40.0	6561	76.0	6561	-	6561	34	1.5	7	6	3	-
113	8/12	0940	33°00'	132°28'	3.0	3750	32.0	3750	72.0	3750	-	4696	36	1.5	8	6	3	-
114	8/12	1440	31°24'	133°45'	-	9375	-	9375	5.0	9375	-	9375	28	2	5	6	3	-
116	8/13	0850	31°40'	135°48'	3.5	3750	53.0	3750	72.0 (69.5)	4696	-	4696	30	2	8	6	3	-
-	8/13	1440	31°22'	136°37'	-	-	-	-	-	-	-	-	32	2	2	4,8	3	Cable broke
-	8/14	1440	29°51'	140°03'	-	7500	-	-	-	-	-	-	28	2	6	4,8	3	+9 zone time, photometer reading
-	8/15	1440	28°18'	143°16'	-	7500	-	-	-	-	-	-	32	2	6	6,8	3	Abandoned
-	8/16	1440	26°35'	146°16'	-	11,250	-	-	-	-	-	-	38	2	2	1,5,8	3	-
-	8/17	1340	25°11'	149°40'	-	11,250	-	-	-	-	-	-	36	2	6	6,8	3	+10 zone time, angle 15°
-	8/18	1340	23°39'	152°55'	-	11,250	-	-	-	-	-	-	34	2	3	6,8	3	Angle 30°
-	8/19	1340	22°07'	156°06'	-	10,500	-	-	-	-	-	-	34	2	6	6,8	4	-

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1/ Coded according to U.S.N.H.O. Pub. 606-c (1956).

Table 8.--Secchi disc data - NEPAS contract vessels

Vessel	Time LCT	Date	Latitude north	Longitude west	Secchi disc m.
Lancing	1200	7/22	45°03'	126°22'	16
Track 3	1200	7/23	44°56'	128°30'	19
	1200	7/24	45°05'	129°18'	14
	1200	7/25	45°00'	131°35'	15
	1200	7/26	45°00'	132°54'	12
	1200	7/27	44°20'	133°25'	11
	1200	7/28	44°32'	131°28'	17
	1200	7/29	44°19'	130°15'	13
	1200	7/30	44°19'	128°20'	16
	1200	7/31	44°20'	126°13'	12
Gypsy	1200	7/22	43°35'	125°48'	16
Track 4	1215	7/23	43°34'	127°45'	27
	1200	7/24	43°43'	128°58'	25
	1200	7/25	43°38'	130°35'	14
	1200	7/26	43°43'	132°15'	17
	1200	7/27	43°28'	133°25'	17
	1200	7/28	42°58'	132°03'	21
	1200	7/29	42°56'	130°20'	21
	1200	7/30	43°02'	128°37'	24
	1200	7/31	42°56'	126°51'	21
Flicker	ca. 1200	7/22	42°20'	126°04'	20
Track 5	"	7/23	43°20'	127°46'	20
	"	7/24	42°20'	129°21'	19
	"	7/25	42°21'	130°56'	18
	"	7/26	42°22'	131°34'	15
	"	7/27	41°40'	132°39'	20
	"	7/28	41°36'	130°53'	22
	"	7/29	41°30'	129°13'	16
	"	7/30	41°36'	127°45'	20
	"	7/31	41°40'	126°18'	22
Lynn Ann	1330	7/27	40°51'	132°52'	22
Track 6	1130	7/28	40°20'	131°54'	21
	1215	7/29	40°20'	130°19'	16
	1200	7/30	41°26'	128°27'	24
	1215	7/31	40°22'	126°42'	22
Rowland R. Sr.	1230	7/22	39°37'	125°35'	17
Track 7	1205	7/23	39°44'	127°00'	22
	1300	7/24	39°36'	128°30'	25
	1240	7/25	40°00'	129°16'	30
	1210	7/26	39°43'	131°24'	24
	1205	7/27	39°21'	131°11'	30
	1205	7/28	38°45'	131°57'	40
	1205	7/29	39°00'	130°05'	28
	1208	7/30	38°53'	128°25'	29
	1205	7/31	38°56'	127°22'	25
Allen Cody	1200	7/23	38°15'	125°05'	14
Track 8	1200	7/24	38°18'	126°32'	15
	1200	7/25	38°22'	127°49'	17
	1200	7/26	38°23'	129°31'	20
	1200	7/27	38°21'	131°10'	19

Table 8. --Secchi disc data - NEPAS contract vessels (cont'd)

Vessel	Time LCT	Date	Latitude north	Longitude west	Secchi disc m.
Allen Cody	1200	7/28	37°36'	129°55'	22
Track 8	1200	7/29	37°37'	128°22'	22
	1200	7/30	37°40'	126°56'	16
	1200	7/31	37°40'	125°34'	16
Tuna Clipper	1200	7/22	37°00'	123°30'	8
Track 9					
Luwella	1200	7/22	35°45'	122°40'	16
Track 10	1200	7/23	35°45'	123°37'	18
	1200	7/24	35°32'	124°39'	18
	1200	7/25	35°35'	125°14'	22
	1200	7/26	35°45'	127°40'	21
	1200	7/27	35°45'	129°24'	26
	1200	7/28	35°02'	128°25'	30
	1200	7/29	35°07'	126°47'	33
	1200	7/30	34°52'	125°00'	26
	1200	7/31	34°55'	123°20'	17
	1200	8/1	34°49'	121°48'	13

Table 9.--Station curves and observed oceanographic data
Hugh M. Smith cruise 40

Notes on Oceanographic Station Curves

Thermosteric anomaly (oblique lines) are in centiliters per ton (Montgomery 1954). Where temperatures of paired thermometers differed by more than 0.05°C. below 300 m. or more 0.10°C. above 300 m., both values are plotted and designated by the symbol △ △ •. The other variables are plotted for each of the temperature values, see station 12. When the station curve is not drawn through a plotted value, it is considered a gross error and not used.

Explanatory code for station curves:

△ Reversing thermometer temperatures °C.

• BT temperature °C.

⊡ Salinity ‰.

▽ Dissolved oxygen ml./L.

⊙ Inorganic phosphate µg. at./L.

Notes on Observed Oceanographic Data

Where more than one cast was made on a station, they are separated by a horizontal line. The cast number is indicated by a Roman numeral in the margin.

Where the corrected, paired, protected thermometer readings differed by more than 0.05°C. below 300 m. or more than 0.10°C. above 300 m., both temperature values are tabulated and the depth and salinity are repeated. Delta-t calculated using each temperature value is carried.

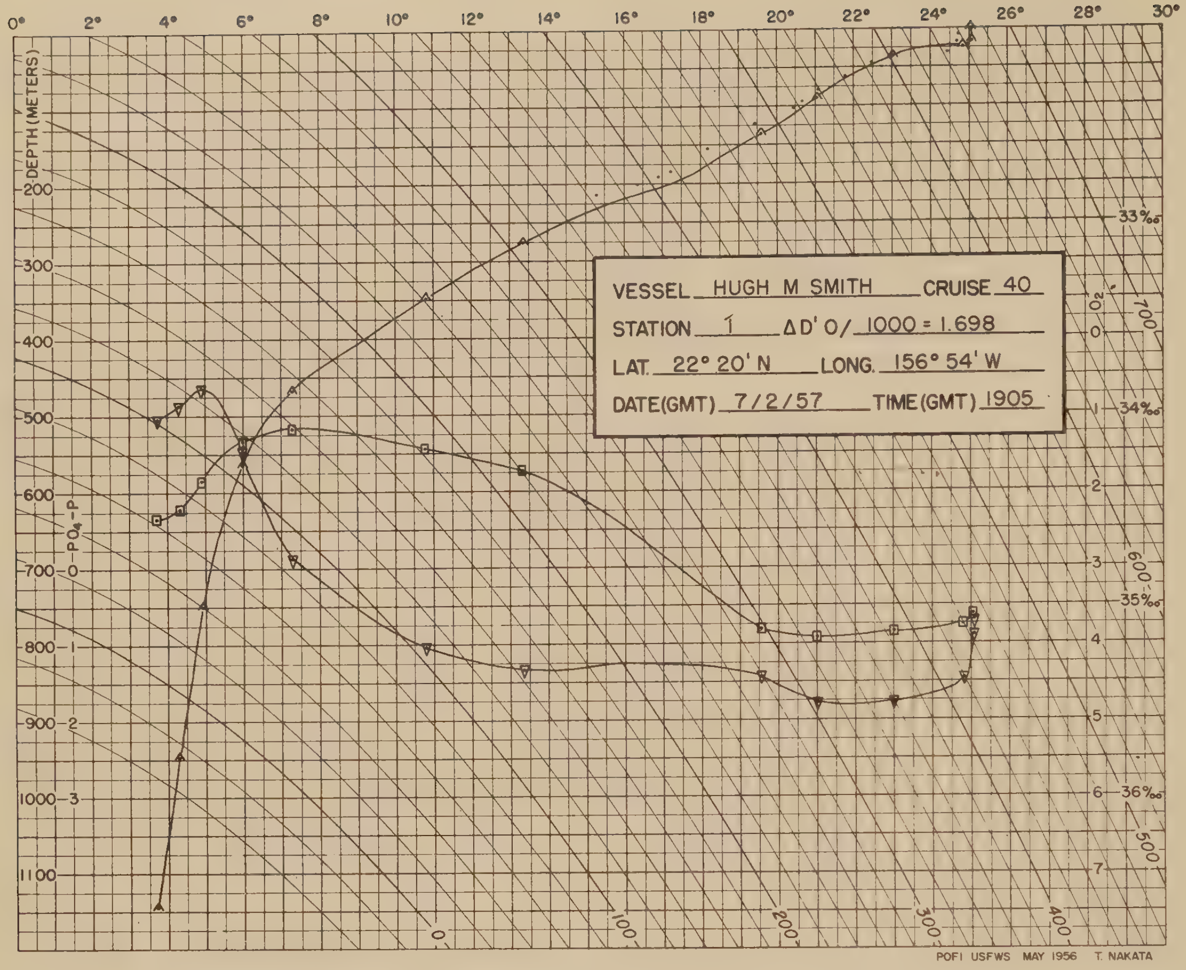
Explanatory code for tabulated data:

NG - The value or line is in error and is discarded.

NS - This water sample was lost.

Q - The value seems questionable but was used in construction of the station curve.

P - The value is questionable and while carried was not used in drawing the station curve.



VESSEL HUGH M SMITH CRUISE 40

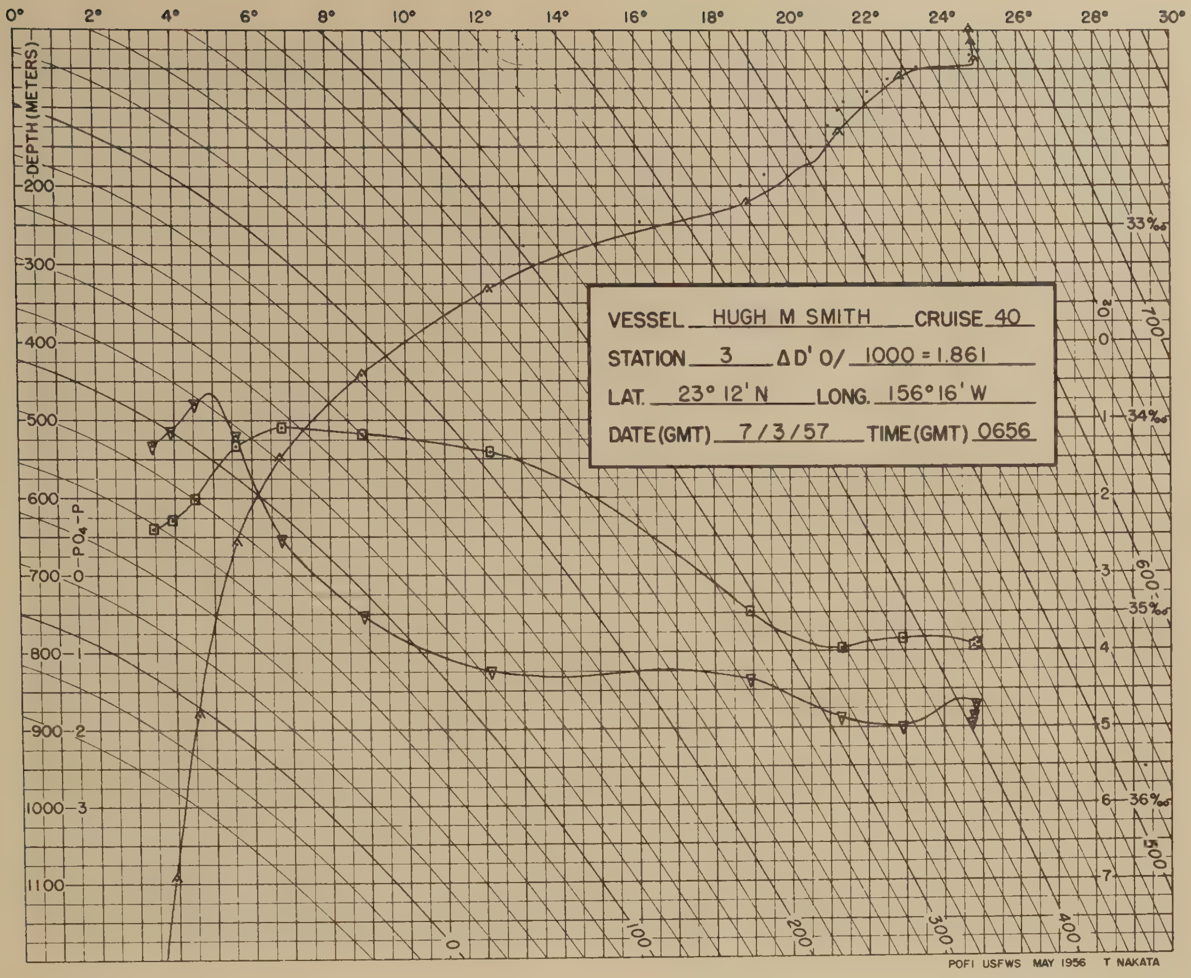
STATION 1 ΔD' 0/1000 = 1.698

LAT. 22° 20' N LONG. 156° 54' W

DATE(GMT) 7/2/57 TIME(GMT) 1905

Weather: 02, cloud coverage 5. Wind: 080°, 21 kt. Sea: 5-8 ft. Wire angle: 55°, 40°.
BT slide: 1. Dry bulb: 77.7°F. Wet bulb: 71.3°F. Barometric pressure: 1021 mb.

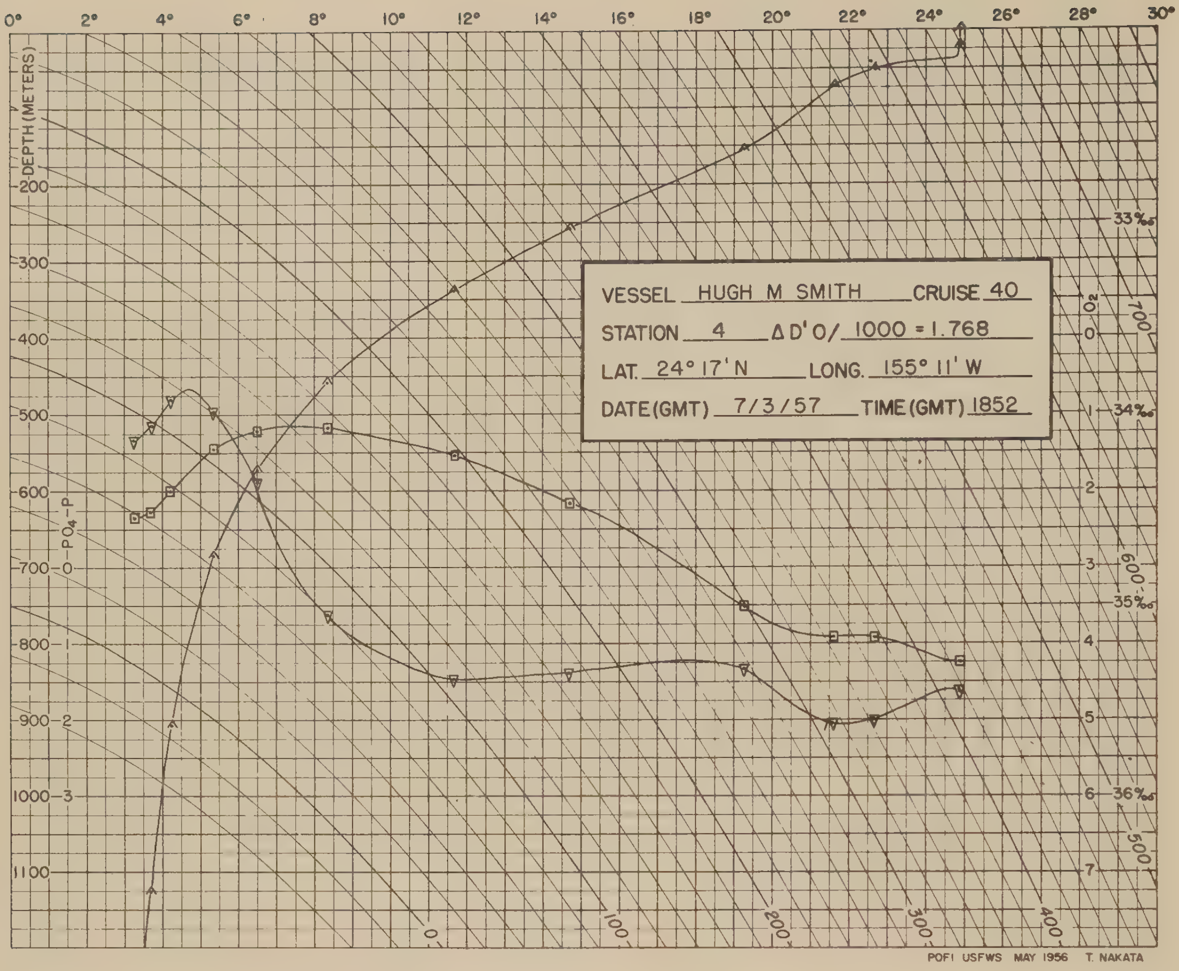
Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	25.08	35.05	451.7	3.68	-
16	25.09	35.07	450.4	3.90	-
21	24.83	35.10	440.9	4.48	-
32	23.02	35.14	386.8	4.76	-
87	21.04	35.17	332.0	4.78	-
I 137	19.59	35.12	298.8	4.43	-
II 277	13.35	34.29	221.4	4.36	-
349	10.81	34.18	183.5	4.04	-
469	7.29	34.07	138.1	2.86	-
564	5.98	34.14	116.3	1.46	-
751	4.92	34.34	89.3	0.63	-
948	4.32	34.49	71.8	0.88	-
1146	3.74	34.54	62.4	1.06	-



VESSEL HUGH M SMITH CRUISE 40
STATION 3 ΔD' 0/1000 = 1.861
LAT. 23° 12' N LONG. 156° 16' W
DATE (GMT) 7/3/57 TIME (GMT) 0656

Weather: 02, cloud coverage 7. Wind: 060°, 22 kt. Sea: 3-5 ft. Wire angle: 30°. BT slide: 6. Dry bulb: 76.8°F. Wet bulb: 70.3°F. Barometric pressure: 1021 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	24.78	35.16	435.0	4.94	-
14	24.80	35.17	434.9	4.86	-
37	24.86	35.16	437.4	4.70	-
60	22.92	35.14	384.0	4.98	-
131	21.31	35.19	337.6	4.86	-
222	18.94	34.99	292.4	4.37	-
334	12.18	34.16	208.9	4.23	-
441	8.86	34.07	160.5	3.52	-
551	6.76	34.04	133.4	2.52	-
659	5.60	34.13	112.7	1.20	-
880	4.56	34.40	81.0	0.78	-
1094	3.92	34.51	66.3	1.11	-
1304	3.42	34.56	58.0	1.32	-

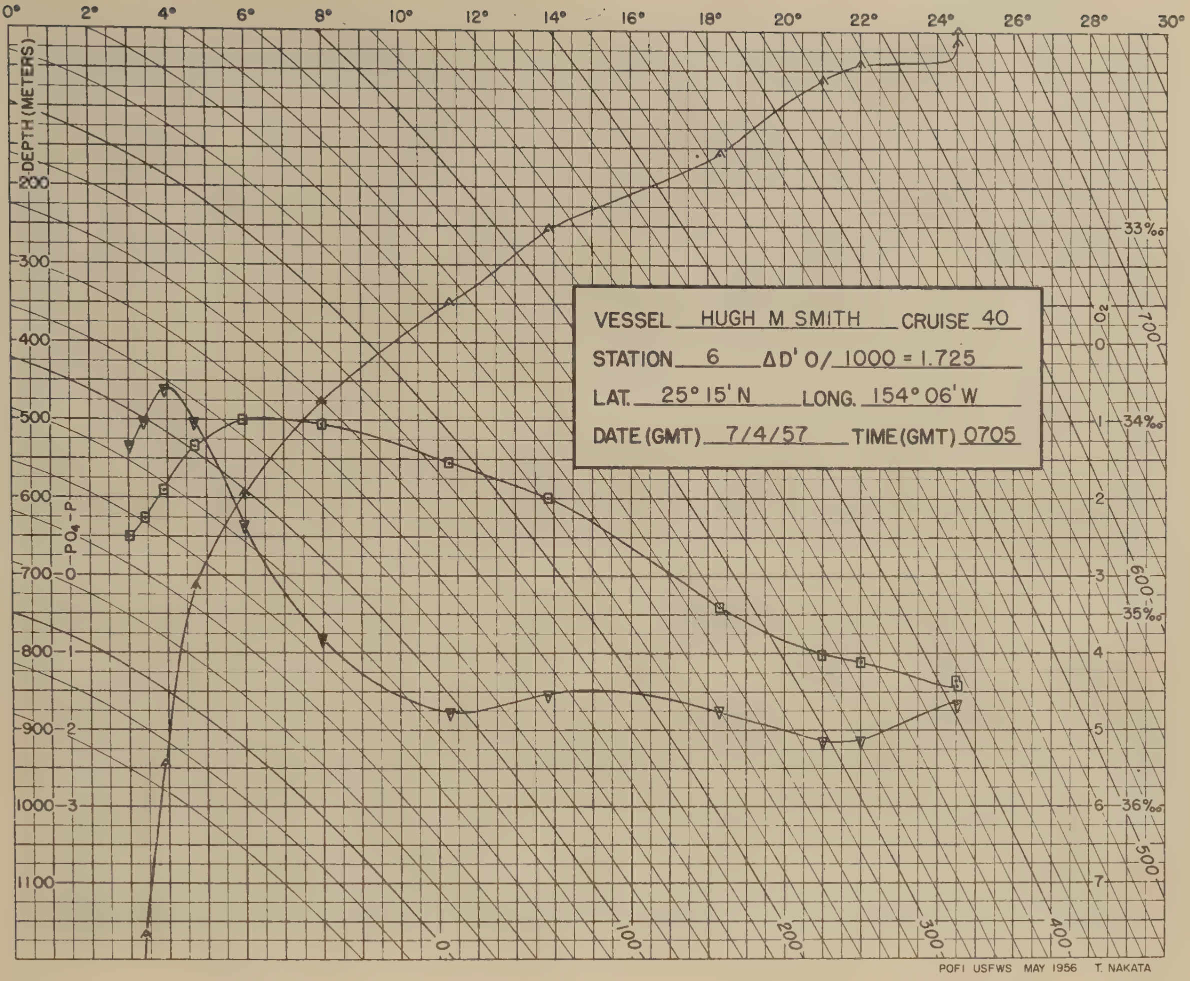


VESSEL HUGH M SMITH CRUISE 40
STATION 4 ΔD'0/1000 = 1.768
LAT. 24° 17' N LONG. 155° 11' W
DATE (GMT) 7/3/57 TIME (GMT) 1852

POFI USFWS MAY 1956 T. NAKATA

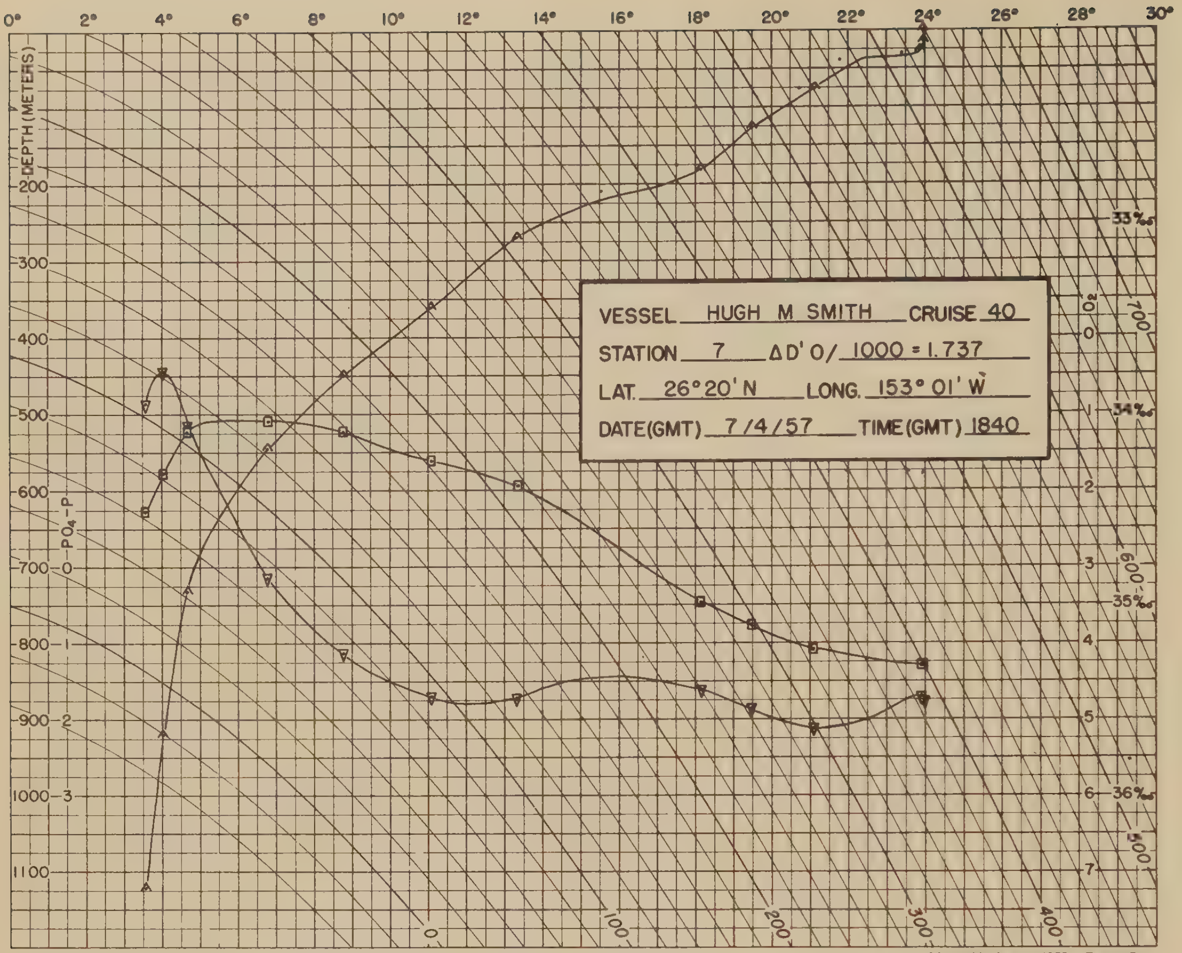
Weather: 02, cloud coverage 2. Wind: 060°, 17 kt. Sea: 1-3 ft. Wire angle: 17°. BT slide: 10. Dry bulb: 77.2°F. Wet bulb: 72.8°F. Barometric pressure: 1019 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	24.88	35.30	427.8	4.63	-
20	24.86	35.30	427.2	4.61	-
51	22.64	35.17	374.3	5.01	-
72	21.61	35.17	346.9	5.05	-
154	19.26	35.01	298.6	4.33	-
257	14.70	34.47	235.1	4.38	-
339	11.67	34.22	195.4	4.46	-
458	8.37	34.07	153.2	3.61	-
572	6.54	34.09	127.0	1.89	-
685	5.36	34.18	106.2	0.96	-
907	4.24	34.40	77.7	0.80	-
1128	3.70	34.51	64.2	1.14	-
1339	3.24	34.54	57.8	1.33	-



Weather: 02, cloud coverage 2. Wind: 080°, 16 kt. Sea: 1-3 ft. Wire angle: 06°. BT slide: 14. Dry bulb: 76.6°F. Wet bulb: 71.3°F. Barometric pressure: 1019 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	24.50	35.35	413.3	4.67	-
15	24.52	35.37	412.5	4.65	-
42	21.96	35.25	350.3	5.13	-
63	20.98	35.21	327.5	5.15	-
159	18.31	34.96	279.3	4.77	-
255	13.85	34.40	223.2	4.53	-
351	11.28	34.22	188.7	4.78	-
476	7.98	34.02	151.2	3.82	-
596	5.96	34.00	126.5	2.34	-
715	4.72	34.14	102.2	1.03	-
944	3.91	34.36	77.5	0.61	-
1169	3.39	34.51	61.4	1.01	-
1380	3.02	34.60	51.3	1.34	-

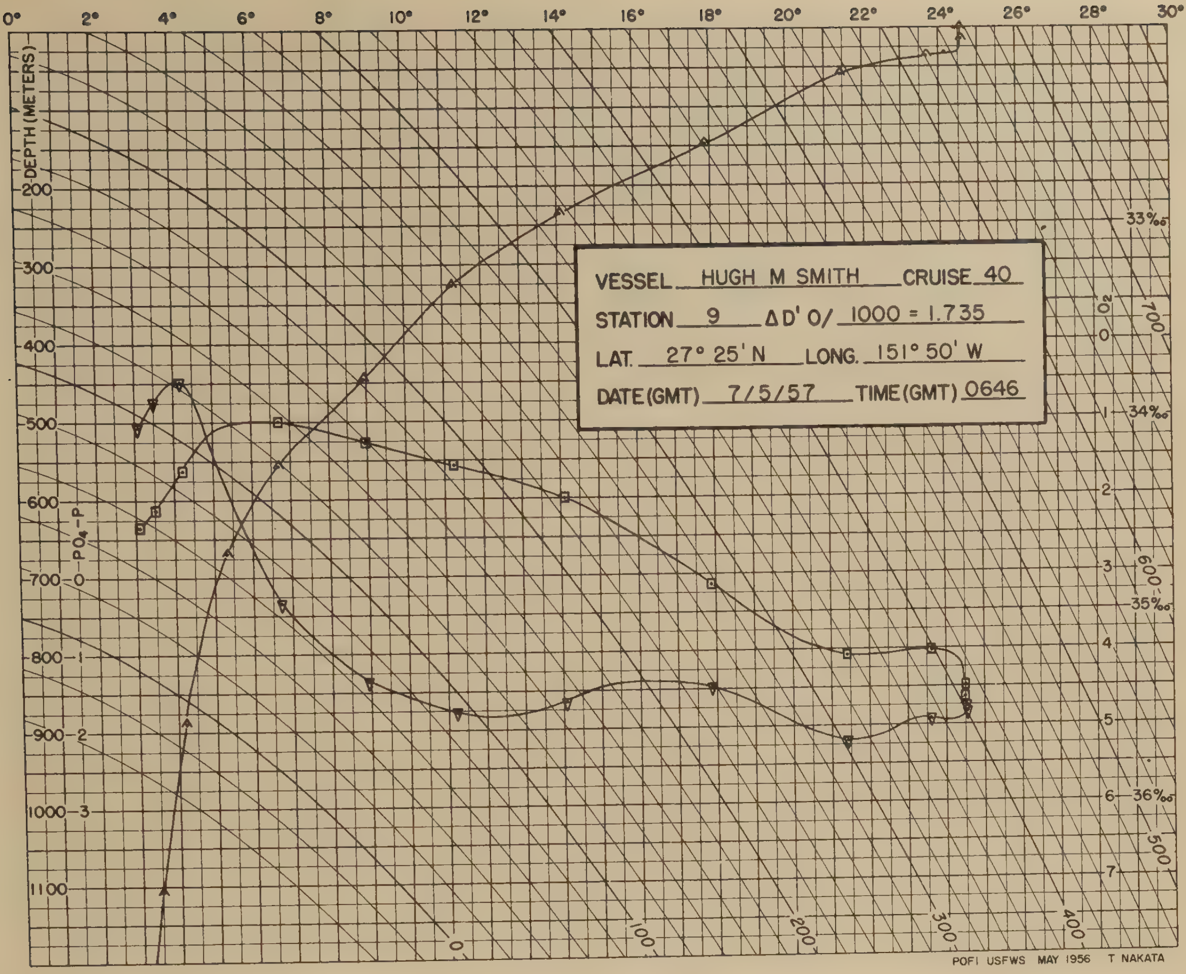


VESSEL HUGH M SMITH CRUISE 40
STATION 7 ΔD' 0/ 1000 = 1.737
LAT. 26° 20' N LONG. 153° 01' W
DATE (GMT) 7/4/57 TIME (GMT) 1840

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 2. Wind: 070°, 11 kt. Sea: 1-3 ft. Wire angle: 27°. BT slide: 17. Dry bulb: 75.3°F. Wet bulb: 70.8°F. Barometric pressure: 1023 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	23.96	35.32	400.1	4.76	-
13	23.96	35.32	400.1	4.73	-
26	23.87	35.32	397.4	4.70	-
75	21.09	35.23	328.9	5.12	-
128	19.47	35.10	297.2	4.86	-
181	18.15	34.99	273.3	4.60	-
269	13.35	34.38	214.8	4.72	-
362	11.09	34.25	183.0	4.70	-
450	8.80	34.09	158.1	4.13	-
545	6.81	34.04	134.1	3.14	-
732	4.68	34.09	105.5	1.15	-
920	4.04	34.31	82.5	0.44	-
1122	3.60	34.51	63.3	0.86	-



VESSEL HUGH M SMITH CRUISE 40

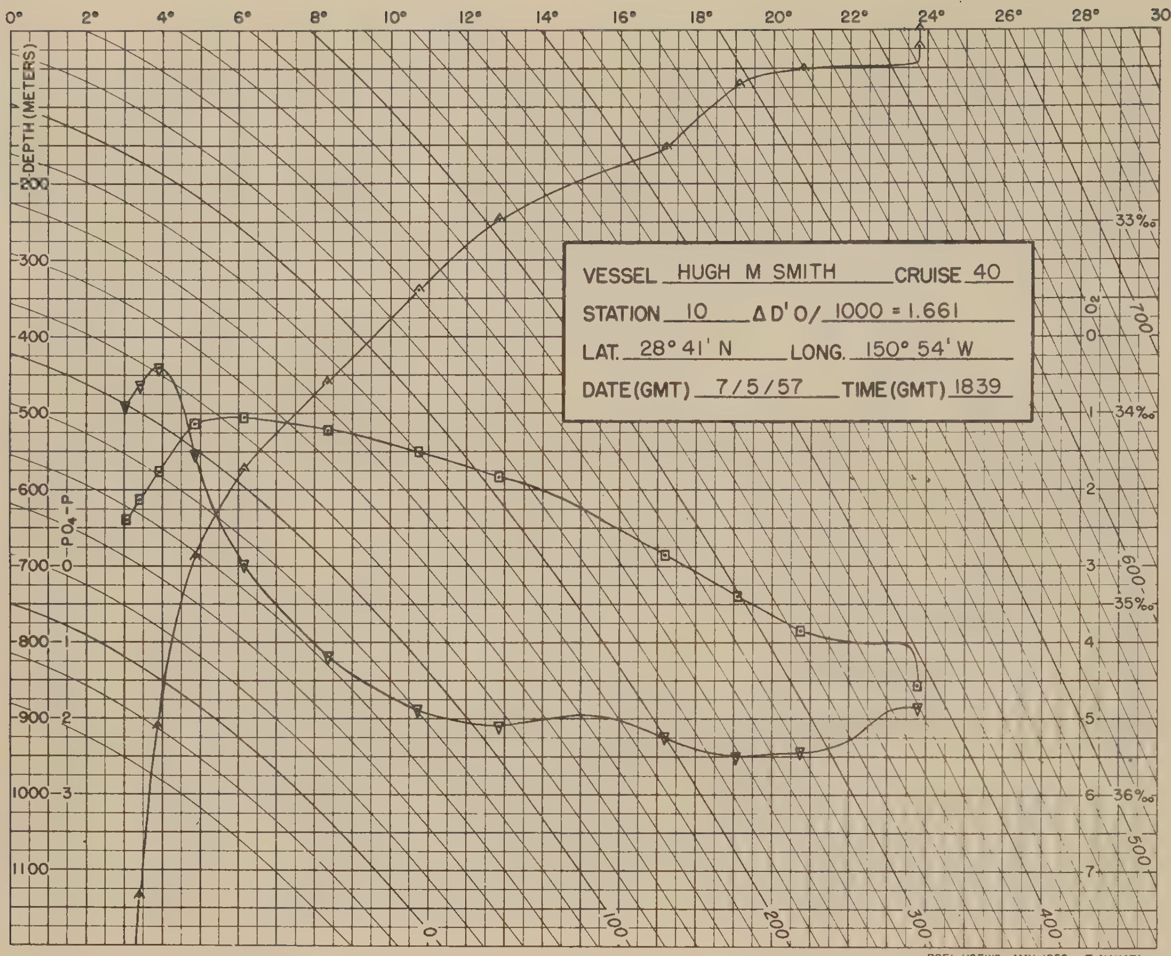
STATION 9 ΔD' 0/ 1000 = 1.735

LAT. 27° 25' N LONG. 151° 50' W

DATE (GMT) 7/5/57 TIME (GMT) 0646

Weather: 03, cloud coverage 6. Wind: 090°, 15 kt. Sea: 1-3 ft. Wire angle: 19°. BT slide: 22. Dry bulb: 75.3°F. Wet bulb: 70.2°F. Barometric pressure: 1025 mb.

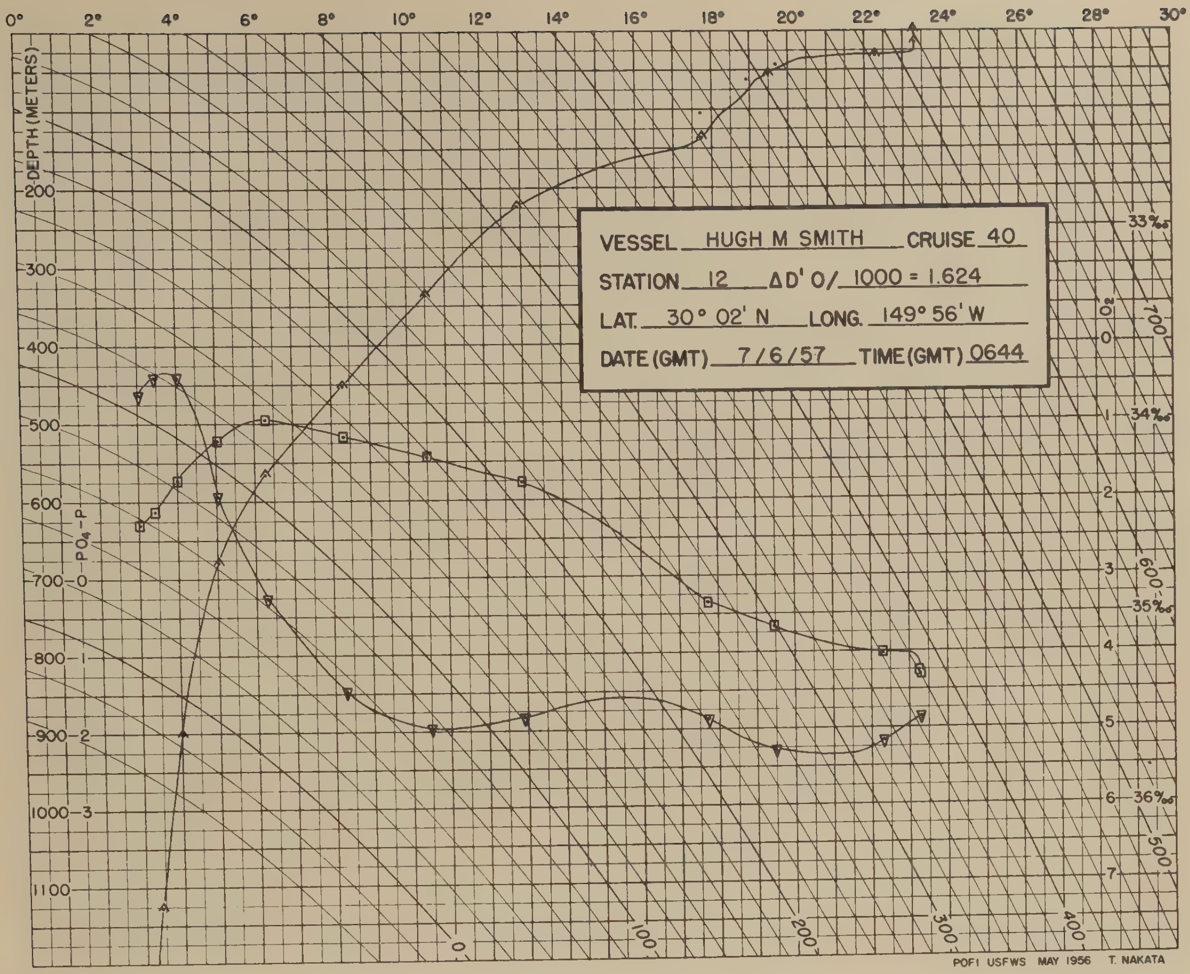
Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	24.54	35.46	406.6	4.75	-
14	24.55	35.39	411.9	4.80	-
34	23.62	35.21	398.3	4.92	-
58	21.40	35.23	337.0	5.18	-
146	17.88	34.85	277.1	4.46	-
236	14.08	34.40	227.7	4.65	-
327	11.23	34.23	186.9	4.76	-
444	8.96	34.11	159.1	4.36	-
557	6.68	34.00	135.3	3.33	-
669	5.32	NS	-	NS	-
888	4.18	34.25	88.3	0.49	-
1108	3.53	34.45	67.2	0.73	-
1316	3.08	34.54	56.3	1.07	-



POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 8. Wind: 070°, 18 kt. Sea: 3-5 ft. Wire angle: 19°. BT slide: 26. Dry bulb: 73.8°F. Wet bulb: 69.6°F. Barometric pressure: 1026 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	23.78	35.43	387.0	4.86	-
20	23.78	35.43	387.0	4.85	-
51	20.74	35.14	326.5	5.44	-
71	19.08	34.96	298.1	5.49	-
153	17.20	34.74	269.5	5.26	-
247	12.85	34.33	208.9	5.10	-
339	10.75	34.20	181.0	4.88	-
459	8.37	34.09	151.7	4.19	-
574	6.18	34.02	127.6	2.98	-
688	4.86	34.05	110.4	1.54	-
913	3.89	34.31	80.9	0.40	-
1137	3.41	34.45	66.2	0.63	-
1353	3.04	34.56	54.5	0.91	-

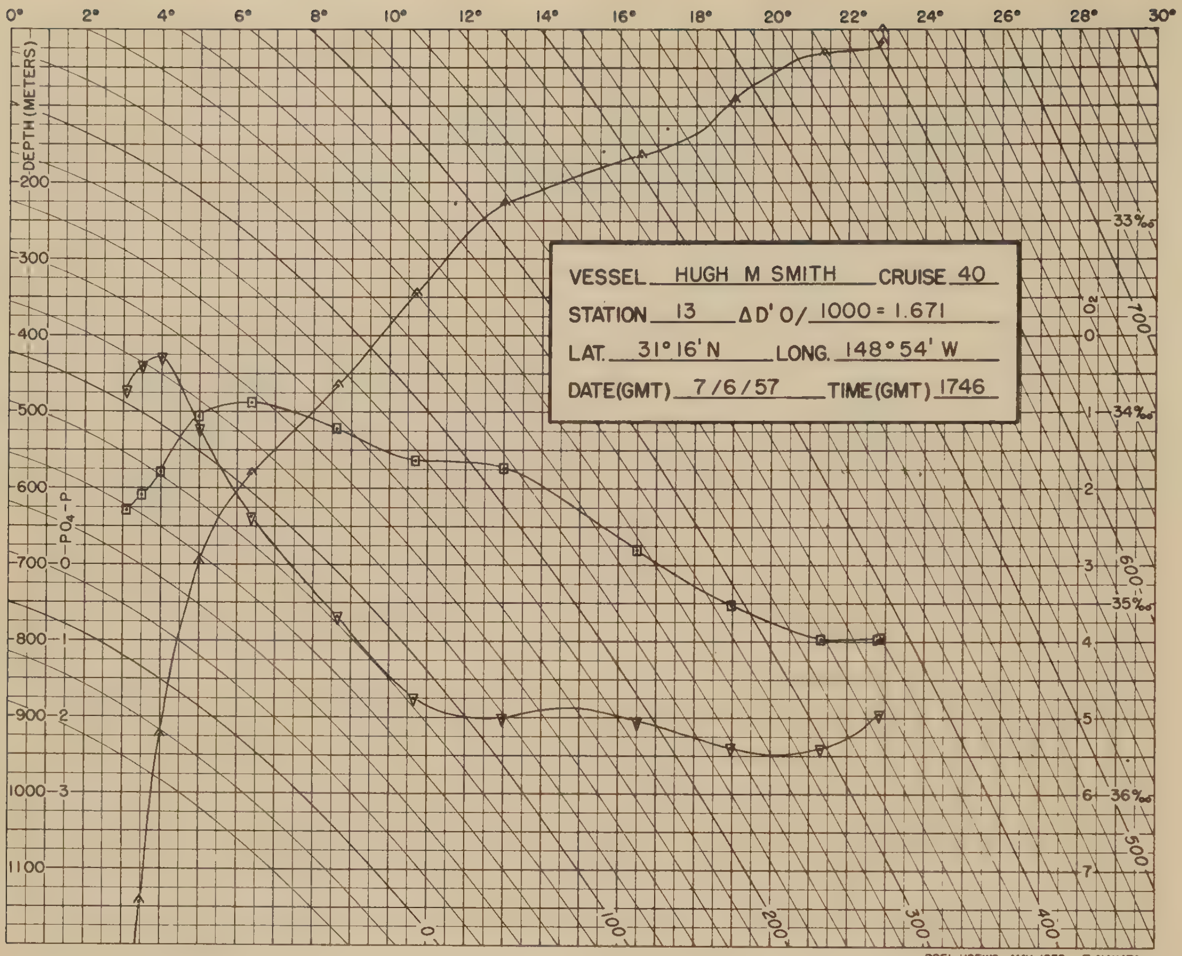


VESSEL HUGH M SMITH CRUISE 40
STATION 12 ΔD' 0/ 1000 = 1.624
LAT. 30° 02' N LONG. 149° 56' W
DATE (GMT) 7/6/57 TIME (GMT) 0644

POFI USFWS MAY 1956 T. NAKATA

Weather: 50, cloud coverage 8. Wind: 070°, 14 kt. Sea: 1-3 ft. Wire angle: 17°. BT slide: 30. Dry bulb: 71.8°F. Wet bulb: 66.8°F. Barometric pressure: 1026 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	23.27	35.32	380.8	4.86	-
15	23.30	35.30	382.9	4.88	-
30	22.30	35.21	362.1	5.17	-
54	19.49	35.07	299.9	5.29	-
136	17.74	34.94	267.5	4.86	-
222	12.92	34.31	211.6	4.82	-
335	10.46	34.18	177.5	4.95	-
452	8.31	34.07	152.5	4.45	-
566	6.32	33.98	132.7	3.24	-
679	5.04	34.09	109.3	1.94	-
903	4.00	34.29	83.6	0.41	-
1127	3.42	34.45	66.3	0.41	-
1342	3.05	34.52	57.5	0.63	-

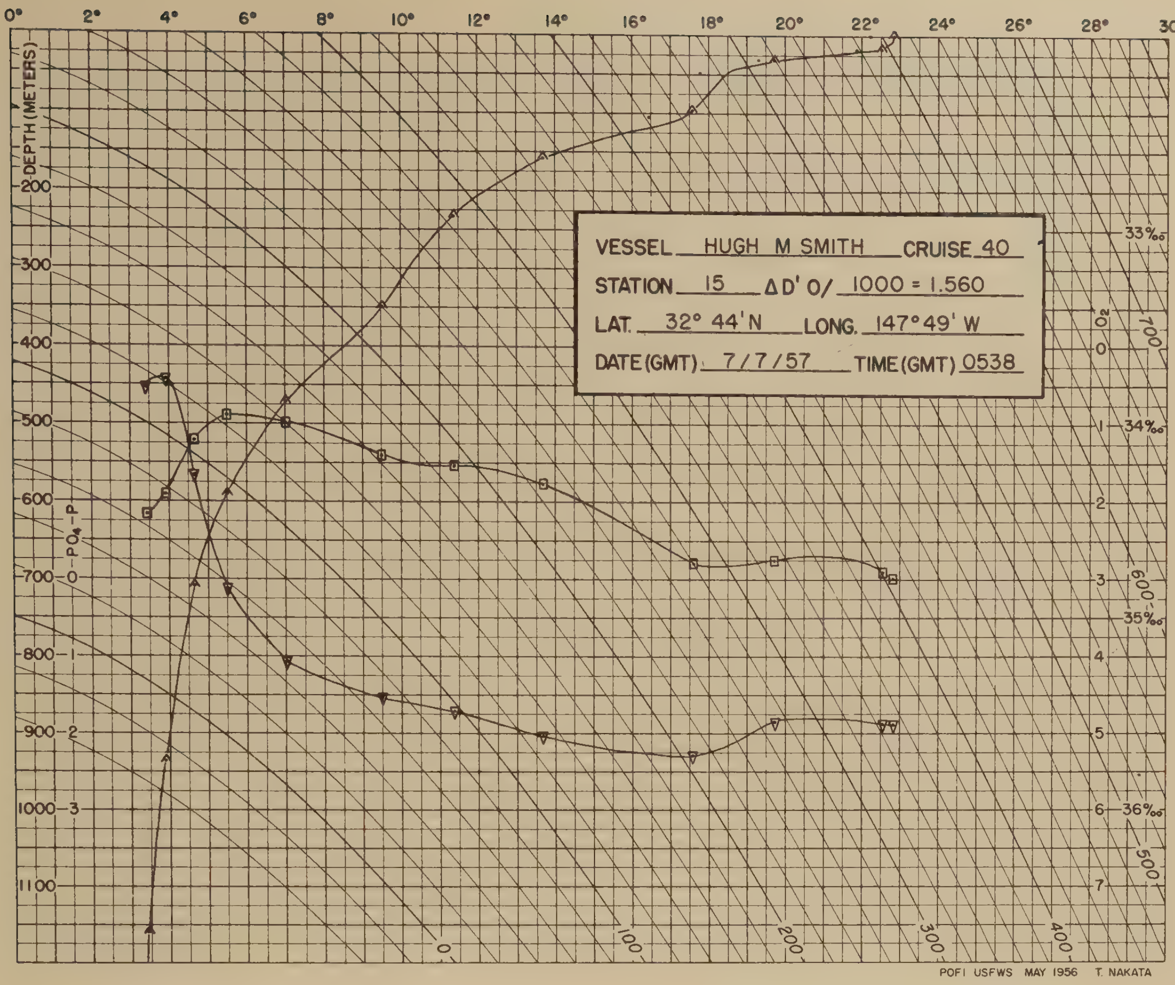


VESSEL HUGH M SMITH CRUISE 40
STATION 13 ΔD' 0/1000 = 1.671
LAT. 31° 16' N LONG. 148° 54' W
DATE(GMT) 7/6/57 TIME(GMT) 1746

POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 8. Wind: 010°, 10 kt. Sea: 1-3 ft. Wire angle: 13°. BT slide: 33. Dry bulb: 72.5°F. Wet bulb: 65.3°F. Barometric pressure: 1026 mb.

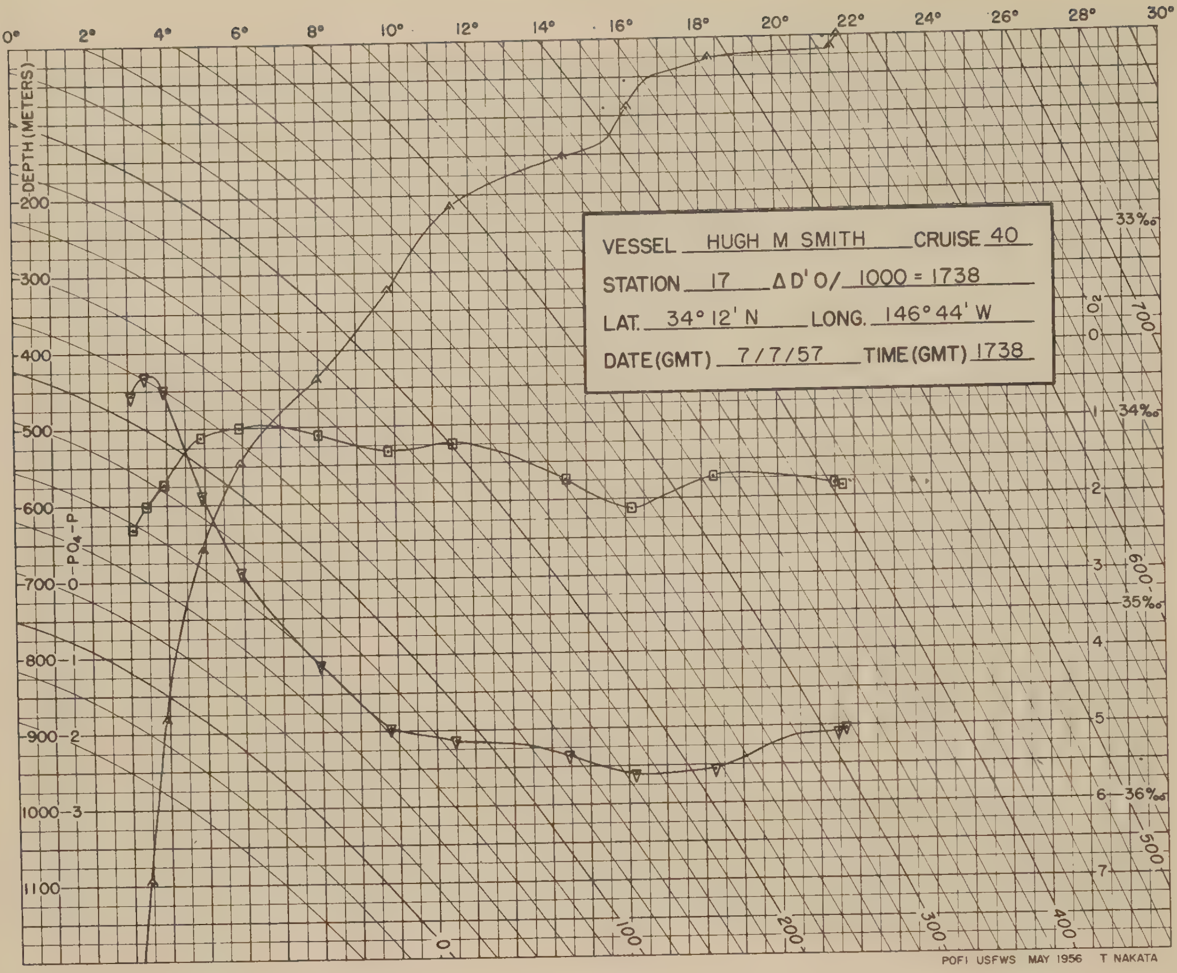
Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O_2, ml. /L.	PO_4-P, µg at. /L.
0	22.82	35.19	377.6	4.94	-
15	22.83	35.19	377.8	4.93	-
30	21.31	35.19	337.5	5.39	-
92	18.96	35.01	291.4	5.40	-
164	16.54	34.72	256.1	5.04	-
227	12.98	34.29	214.1	5.02	-
344	10.66	34.25	175.7	4.74	-
465	8.65	34.09	155.9	3.66	-
581	6.38	33.95	135.5	2.36	-
697	5.00	34.02	114.1	1.20	-
923	4.00	34.31	82.1	0.30	-
1144	3.48	34.43	68.2	0.40	-
1356	3.08	34.52	57.9	0.70	-



VESSEL HUGH M SMITH CRUISE 40
STATION 15 ΔD' 0/ 1000 = 1.560
LAT. 32° 44'N LONG. 147°49' W
DATE (GMT) 7/7/57 TIME (GMT) 0538

Weather: 02, cloud coverage 2. Wind: 080°, 07 kt. Sea: 1-3 ft. Wire angle: 09°. BT slide: 38. Dry bulb: 72.7°F. Wet bulb: 68.3°F. Barometric pressure: 1026 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	22.82	34.79	406.6	4.90	-
16	22.56	34.76	401.7	4.87	-
31	19.73	34.70	332.6	4.85	-
95	17.58	34.72	279.6	5.29	-
159	13.68	34.31	226.3	5.03	-
233	11.38	34.22	190.4	4.71	-
351	9.53	34.16	164.2	4.53	-
473	7.02	34.00	139.5	4.05	-
591	5.48	33.96	124.1	3.11	-
708	4.64	34.09	105.3	1.66	-
935	3.92	34.36	77.7	0.42	-
1159	3.42	34.47	64.8	0.52	-
(1368)	NS	34.52	-	0.93	-

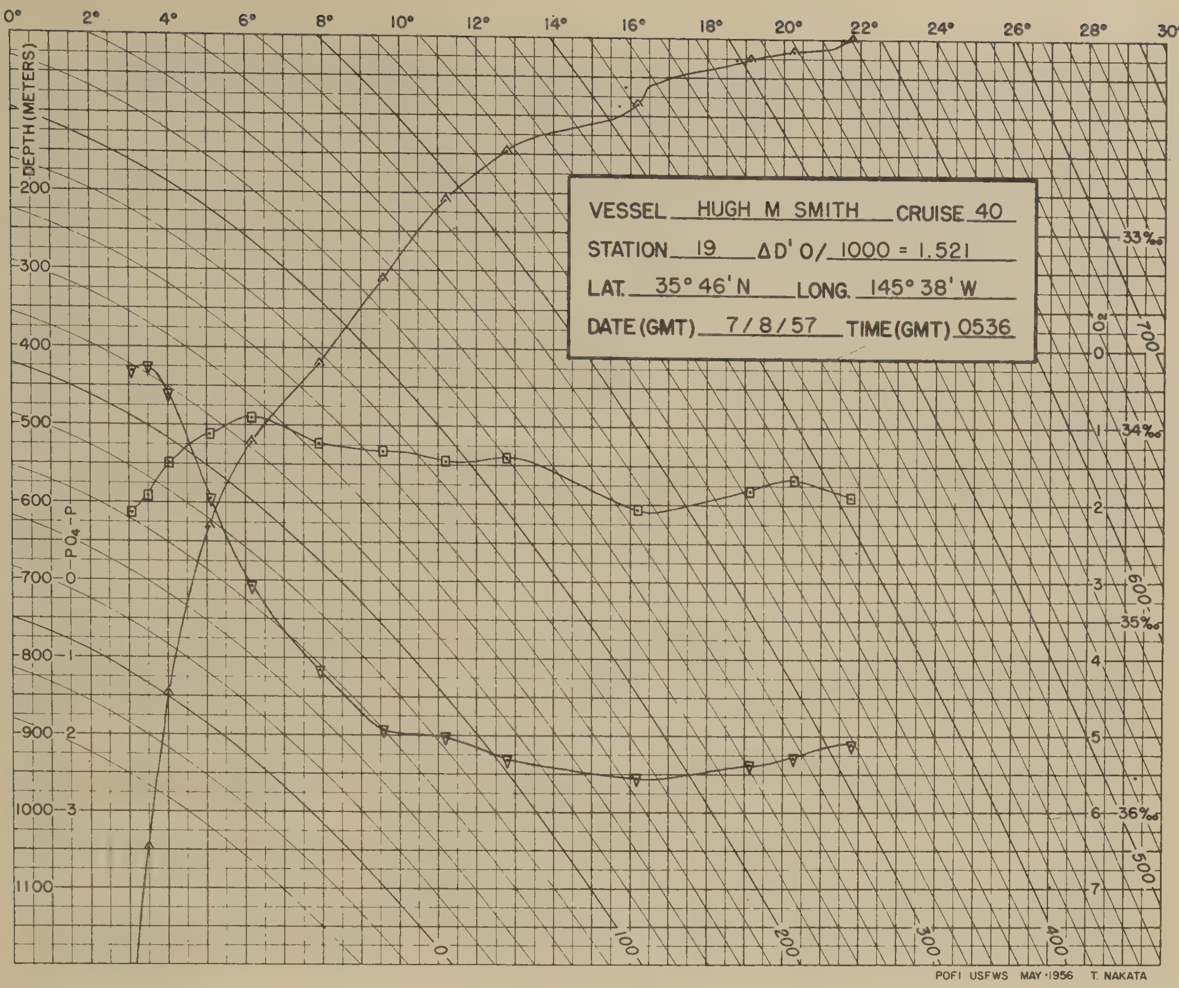


VESSEL HUGH M SMITH CRUISE 40
STATION 17 ΔD'0/1000 = 1738
LAT. 34° 12' N LONG. 146° 44' W
DATE (GMT) 7/7/57 TIME (GMT) 1738

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 1. Wind: 020°, 08 kt. Sea: < 1 ft. Wire angle: 06°. BT slide: 41. Dry bulb: 70.0°F. Wet bulb: 65.8°F. Barometric pressure: 1025 mb.

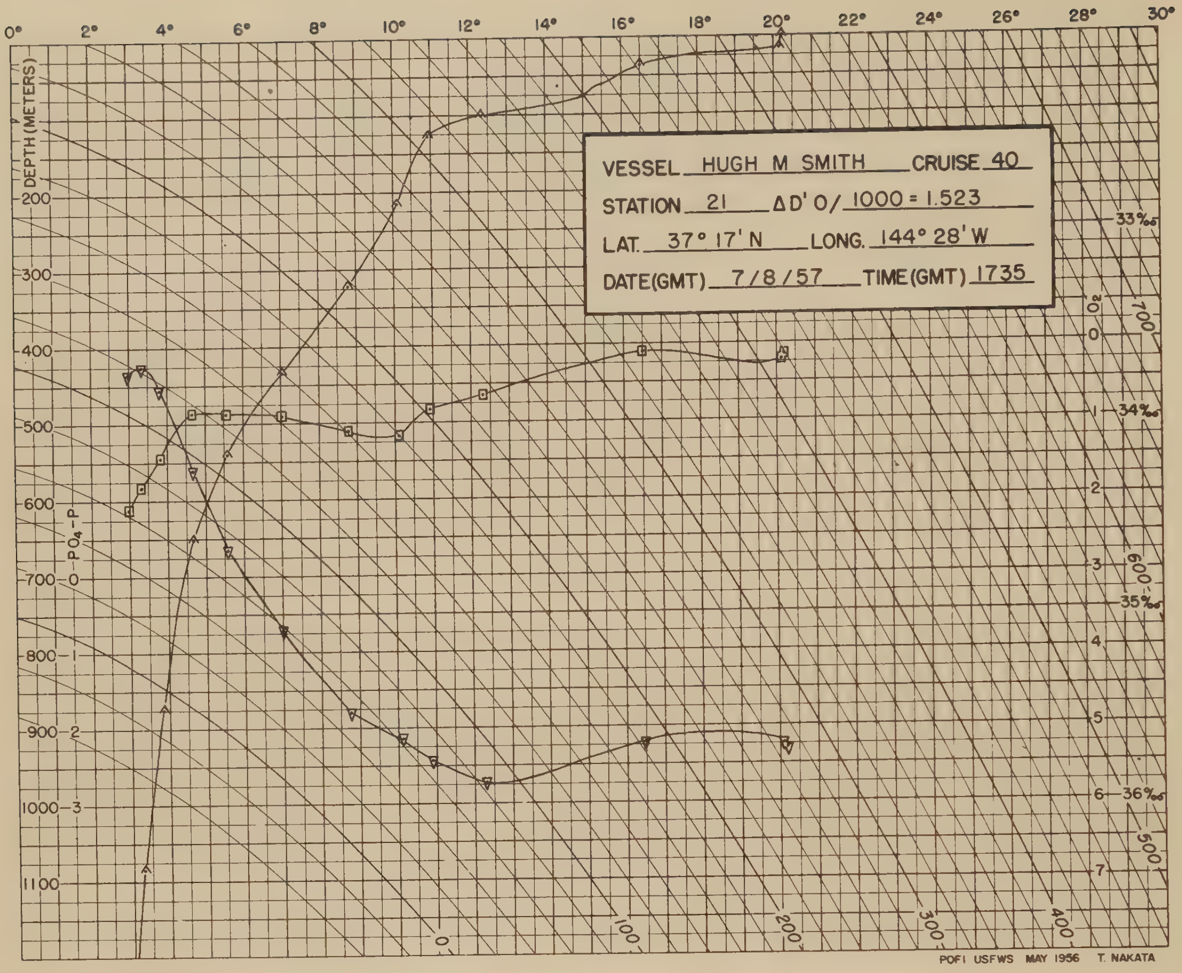
Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O₂, ml./L.	PO₄-P, µg at./L.
0	21.66	34.34	408.0	5.05	-
15	21.45	34.33	403.3	5.08	-
26	18.28	34.29	327.2	5.54	-
89	16.15	34.45	267.1	5.60	-
152	14.46	34.29	243.3	5.34	-
215	11.51	34.09	202.2	5.12	-
323	9.82	34.13	170.9	4.95	-
438	7.96	34.04	149.5	4.11	-
546	5.91	34.00	126.1	2.87	-
659	4.90	34.04	111.6	1.85	-
881	3.92	34.29	82.9	0.49	-
1094	3.42	34.40	70.0	0.31	-
1309	3.06	34.52	57.7	0.54	-



Weather: 03, cloud coverage 2. Wind: 250°, 09 kt. Sea: < 1 ft. Wire angle: 14°. BT slide: 46. Dry bulb: 71.3°F. Wet bulb: 66.8°F. Barometric pressure: 1025 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O_2, ml./L.	PO_4-P, µg at./L.
0	21.78	34.36	409.8	5.11	0.40
15	20.26	34.27	377.1	5.29	0.47
26	19.12	34.33	344.5	5.37	0.15
85	16.16	34.43	268.9	5.55	0.26
146	12.80	34.16	220.4	5.32	0.63
209	11.20	34.18	190.2	5.02	0.82
311	9.58	34.13	167.2	4.93	1.17
420	7.92	34.09	145.3	4.17	1.48
522	6.19	33.96	132.2	3.06	0.98
632	5.10	34.05	113.0	1.94	2.58
846	4.04	34.20	90.8	0.59	3.25
1048	3.47	34.36	73.4	0.26	3.41
1260	3.11	34.45	63.5	0.31	1.67*
1260					1.42*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



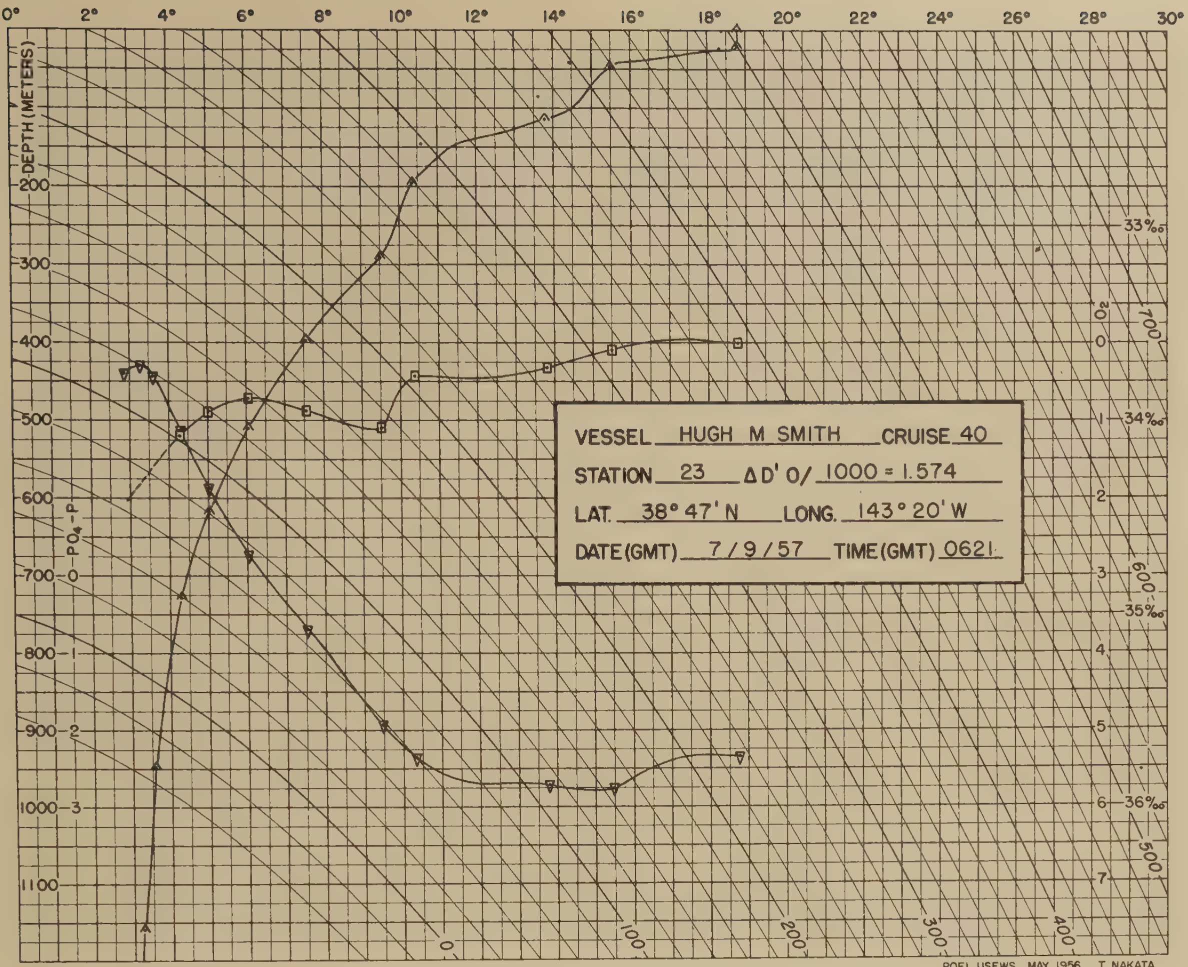
VESSEL HUGH M SMITH CRUISE 40
STATION 21 ΔD' 0/1000 = 1.523
LAT. 37° 17' N LONG. 144° 28' W
DATE (GMT) 7/8/57 TIME (GMT) 1735

POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 1. Wind: 270°, 10 kt. Sea: 1-3 ft. Wire angle: 09°. BT slide: 49. Dry bulb: 68.7°F. Wet bulb: 66.6°F. Barometric pressure: 1023 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	20.18	33.66	419.3	5.29	0.20
16	20.12	33.68	416.2	5.24	0.31
37	16.46	33.64	333.0	5.22	0.02
100	12.32	33.86	233.4	5.72	0.47
126	10.92	33.93	204.5	5.43	0.75
215	10.08	34.07	179.5	5.15	0.90
322	8.79	34.04	161.6	4.79	0.61
434	7.02	33.96	143.1	3.70	0.80
542	5.58	33.95	126.0	2.65	0.70
653	4.67	33.95	116.0	1.62	0.93
874	3.83	34.18	90.3	0.56	3.16
1084	3.34	34.33	74.6	0.27	2.56
1295	2.98	34.45	62.0	0.37	0.98*
1295					0.92*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.

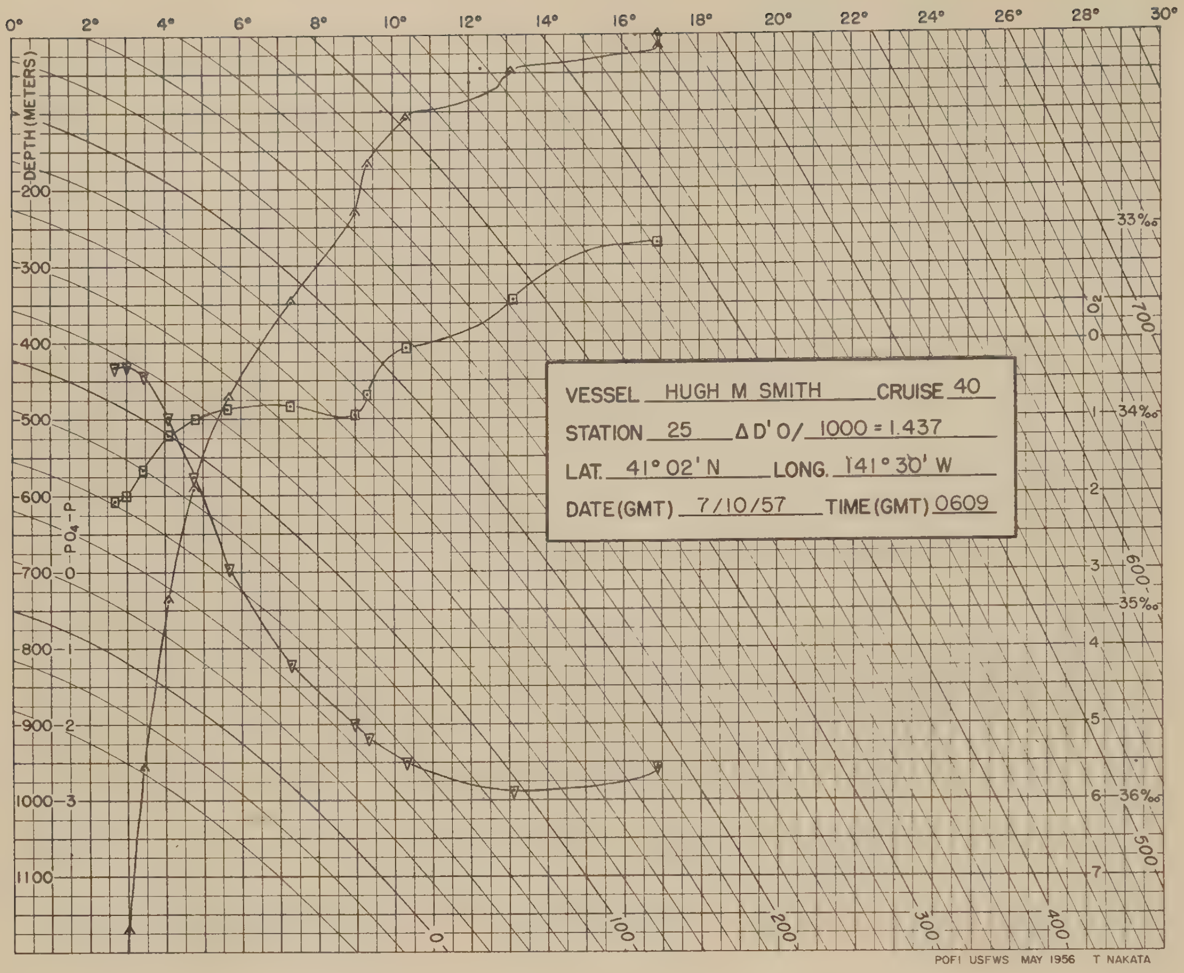


VESSEL HUGH M SMITH CRUISE 40
STATION 23 ΔD' 0/1000 = 1.574
LAT. 38° 47' N LONG. 143° 20' W
DATE (GMT) 7/9/57 TIME (GMT) 0621

POFI USFWS MAY 1956 T. NAKATA

Weather: 03, cloud coverage 8. Wind: 240°, 20 kt. Sea: 3-5 ft. Wire angle: 11°. BT slide: 53A. Dry bulb: 67.8°F. Wet bulb: 66.3°F. Barometric pressure: 1019 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, μg at. /L.
0	18.78	33.60	389.2	5.34	0.37
20	18.78	33.60	389.2	5.34	0.42
45	15.47	33.64	311.5	5.78	0.41
113	13.79	33.73	270.9	5.72	NS
196	10.36	33.77	206.1	5.35	0.76
291	9.48	34.04	172.3	4.93	NS
397	7.58	33.95	151.1	3.70	NS
510	6.04	33.89	135.9	2.74	0.40
617	5.02	33.96	119.0	1.88	NS
729	4.32	34.08	102.7	1.12	1.38
949	3.60	34.24	83.7	0.44	2.30
1160	3.25	34.42	66.9	0.29	NS
1370	2.90	34.46	60.8	0.42	1.81



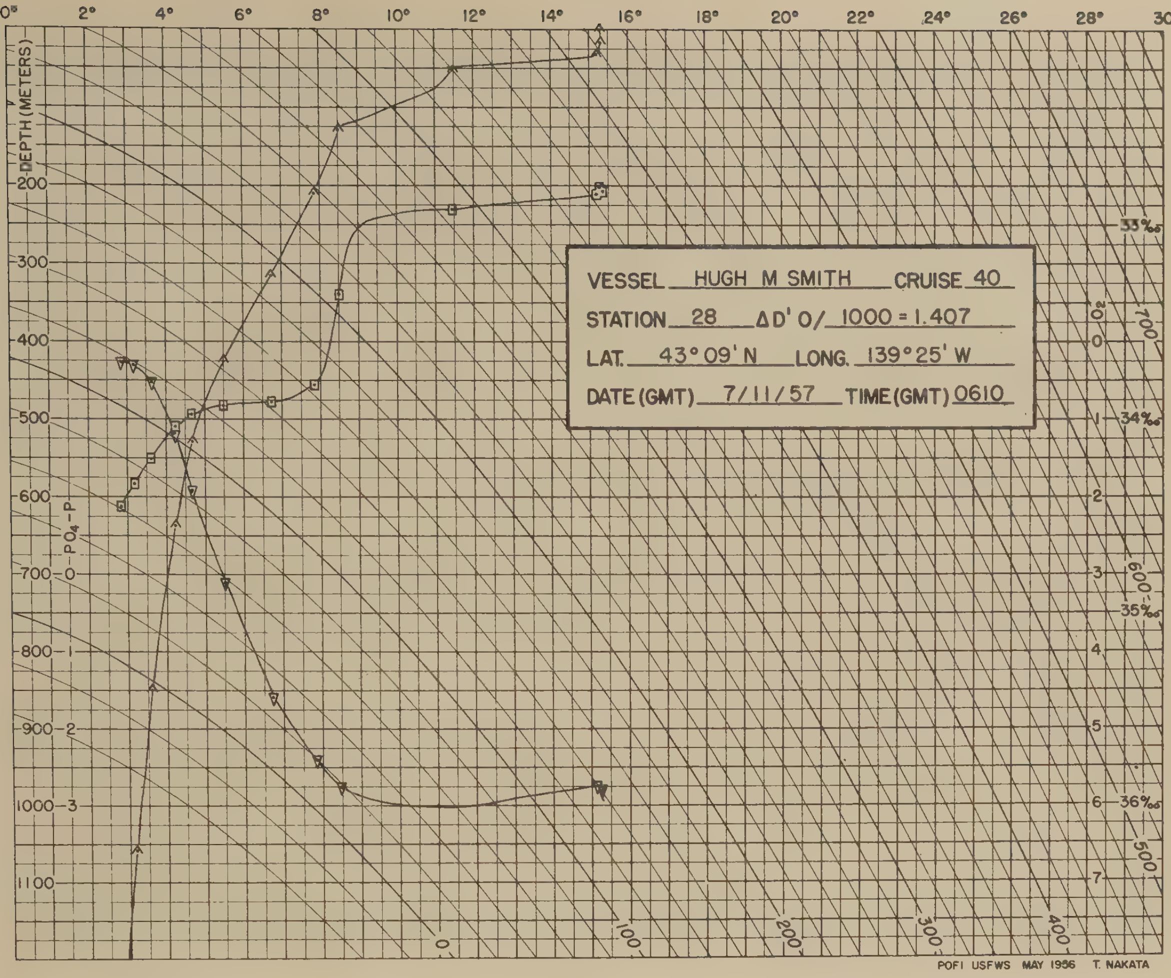
VESSEL HUGH M SMITH CRUISE 40
STATION 25 Δ D' 0/ 1000 = 1.437
LAT. 41° 02' N LONG. 141° 30' W
DATE (GMT) 7/10/57 TIME (GMT) 0609

POFI USFWS MAY 1956 T NAKATA

Weather: 01, cloud coverage 7. Wind: 020°, 21 kt. Sea: 5-8 ft. Wire angle: 05°. BT slide: 62. Dry bulb: 62.3°F. Wet bulb: 60.0°F. Barometric pressure: 1020 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O_2, ml. /L.	PO_4-P, µg at. /L.
0	16.92	33.08	384.0	5.55	0.36
16	16.93	33.08	384.1	5.60	0.40
47	13.11	33.38	283.3	5.87	0.26
109	10.34	33.63	216.3	5.50	0.79
168	9.34	33.87	182.9	5.18	0.72
231	8.99	33.98	169.0	4.98	0.89
348	7.30	33.93	149.0	4.20	0.80
473	5.68	33.95	127.0	2.95	0.89
593	4.75	34.00	113.0	1.75	1.37
738	4.08	34.09	99.4	0.97	2.67
959	3.44	34.27	80.0	0.43	2.91
1171	3.00	34.40	66.1	0.30	2.92
1386	2.70	34.43	61.5	0.32	1.79*
1386					1.60*

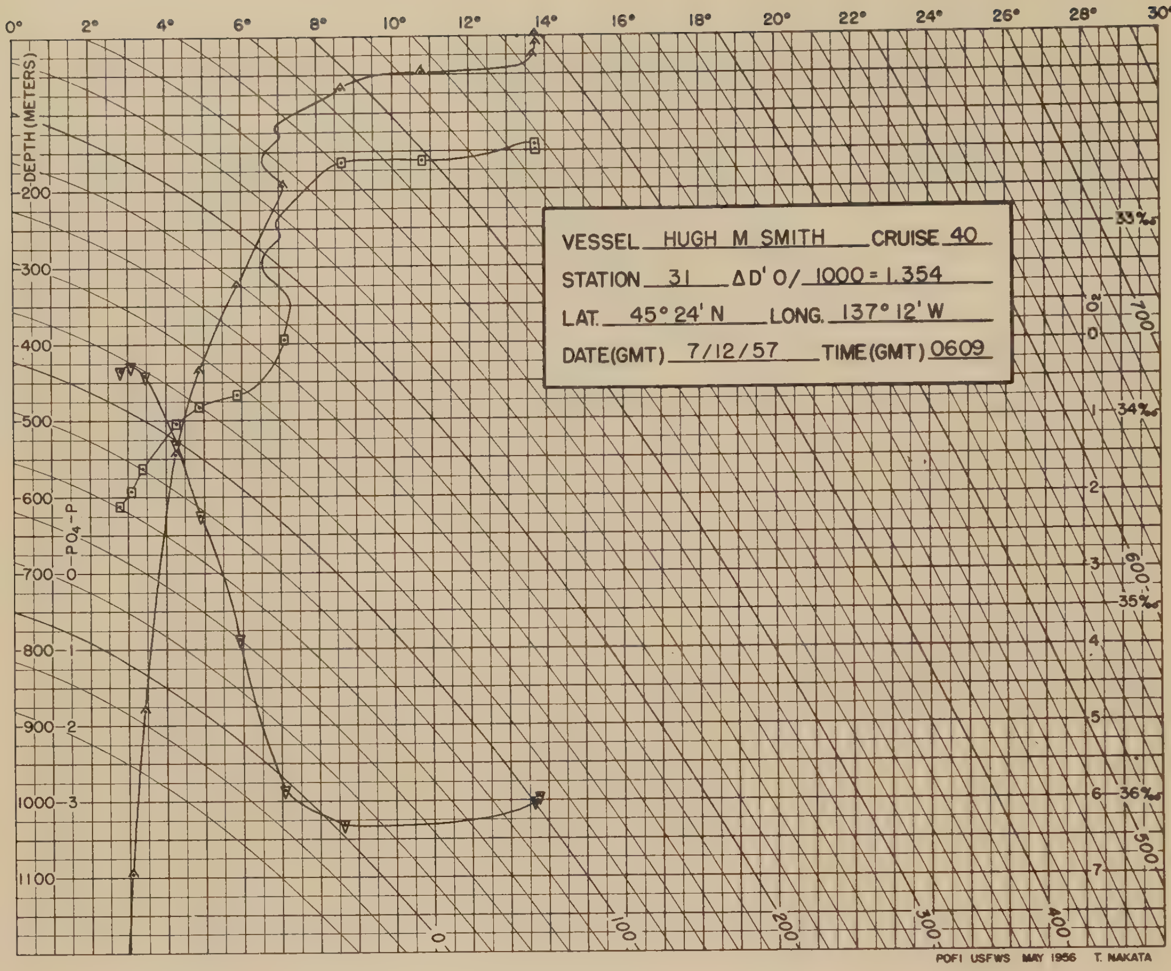
* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



VESSEL HUGH M SMITH CRUISE 40
STATION 28 ΔD' 0/ 1000 = 1.407
LAT. 43° 09' N LONG. 139° 25' W
DATE (GMT) 7/11/57 TIME (GMT) 0610

Weather: 03, cloud coverage 8. Wind: 280°, 10 kt. Sea: 1-3 ft. Wire angle: 14°. BT slide: 73. Dry bulb: 57.5°F. Wet bulb: 53.6°F. Barometric pressure: 1023 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	15.27	32.81	368.3	5.81	0.41
15	15.30	32.83	367.5	5.79	0.38
30	15.18	32.84	364.0	5.76	0.38
51	11.45	32.92	287.1	NG	0.54
128	8.49	33.36	207.8	5.75	1.31
210	7.84	33.82	164.5	5.40	1.31
315	6.74	33.91	143.1	4.59	2.00
425	5.49	33.93	126.4	3.10	2.12
529	4.66	33.98	113.8	1.91	2.10
637	4.22	34.04	104.6	1.20	3.06
850	3.60	34.20	86.7	0.52	3.28
1058	3.17	34.33	72.8	0.31	3.61
1270	2.84	34.45	61.1	0.28	1.66

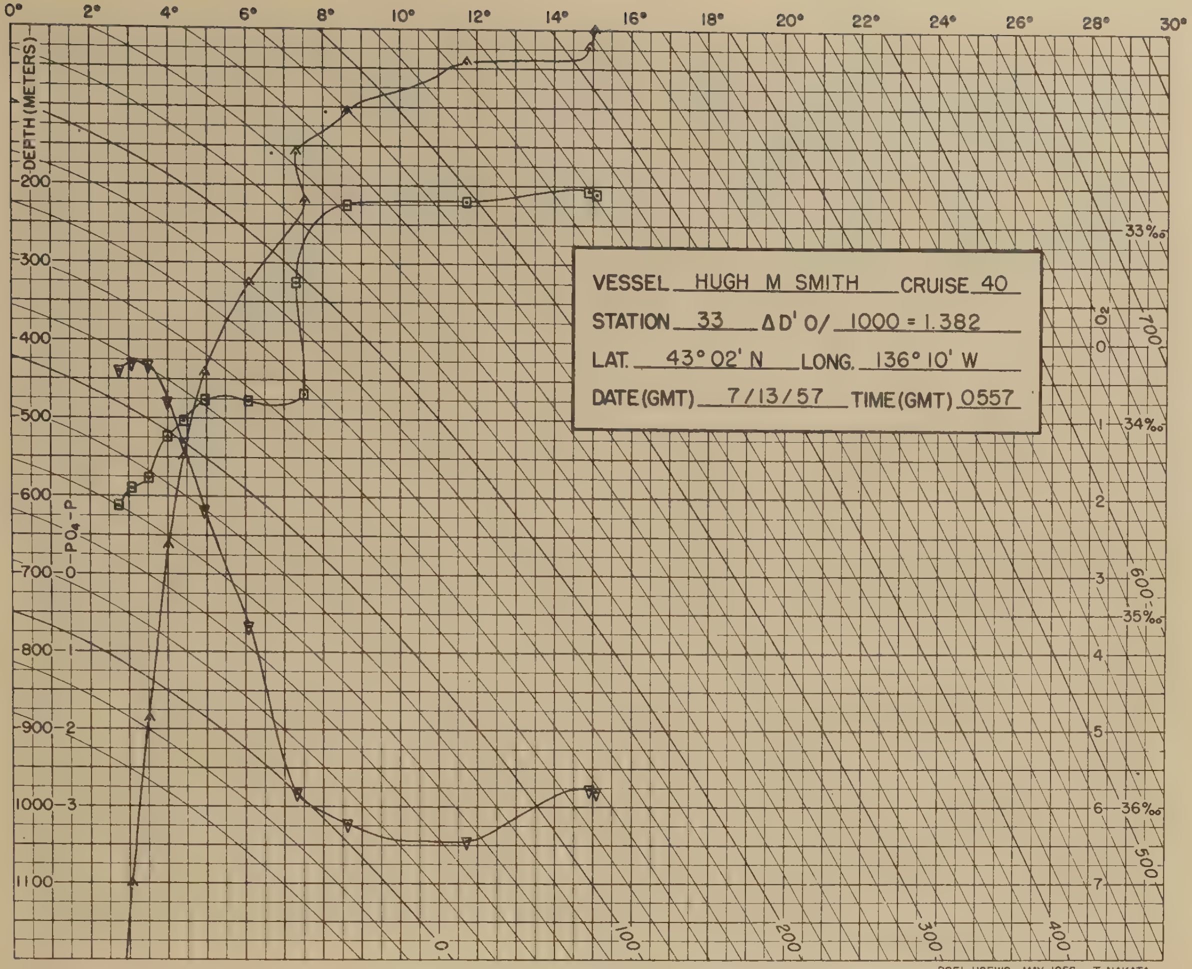


VESSEL HUGH M SMITH CRUISE 40
STATION 31 ΔD' 0/1000 = 1.354
LAT. 45° 24' N LONG. 137° 12' W
DATE (GMT) 7/12/57 TIME (GMT) 0609

Weather: 50, cloud coverage 8. Wind: 150°, 14 kt. Sea: 1-3 ft. Wire angle: 07°. BT slide: 83. Dry bulb: 56.9°F. Wet bulb: 56.4°F. Barometric pressure: 1013 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O_2, ml. /L.	PO_4-P, µg at. /L.
0	13.76	32.57	355.4	5.96	0.59
11	13.75	32.60	353.0	5.96	0.54
26	13.66	32.56	354.1	6.02	0.48
47	10.76	32.65	295.4	NG	0.77
68	8.64	32.66	262.0	6.33	1.25
194	7.11	33.58	172.7	5.85	1.71
324	5.88	33.87	135.3	3.87	1.61
437	4.88	33.93	119.9	2.24	2.15
545	4.28	34.02	106.6	1.31	1.57
659	3.92	34.11	96.5	NG	2.63
881	3.42	34.25	81.3	0.43	2.87
1096	3.06	34.38	68.3	0.30	2.90
1313	2.80	34.45	60.8	0.35	2.42*
1313					2.30*

* Values of duplicate did not agree within 0.02 µg at. /L. tolerance so both are carried.



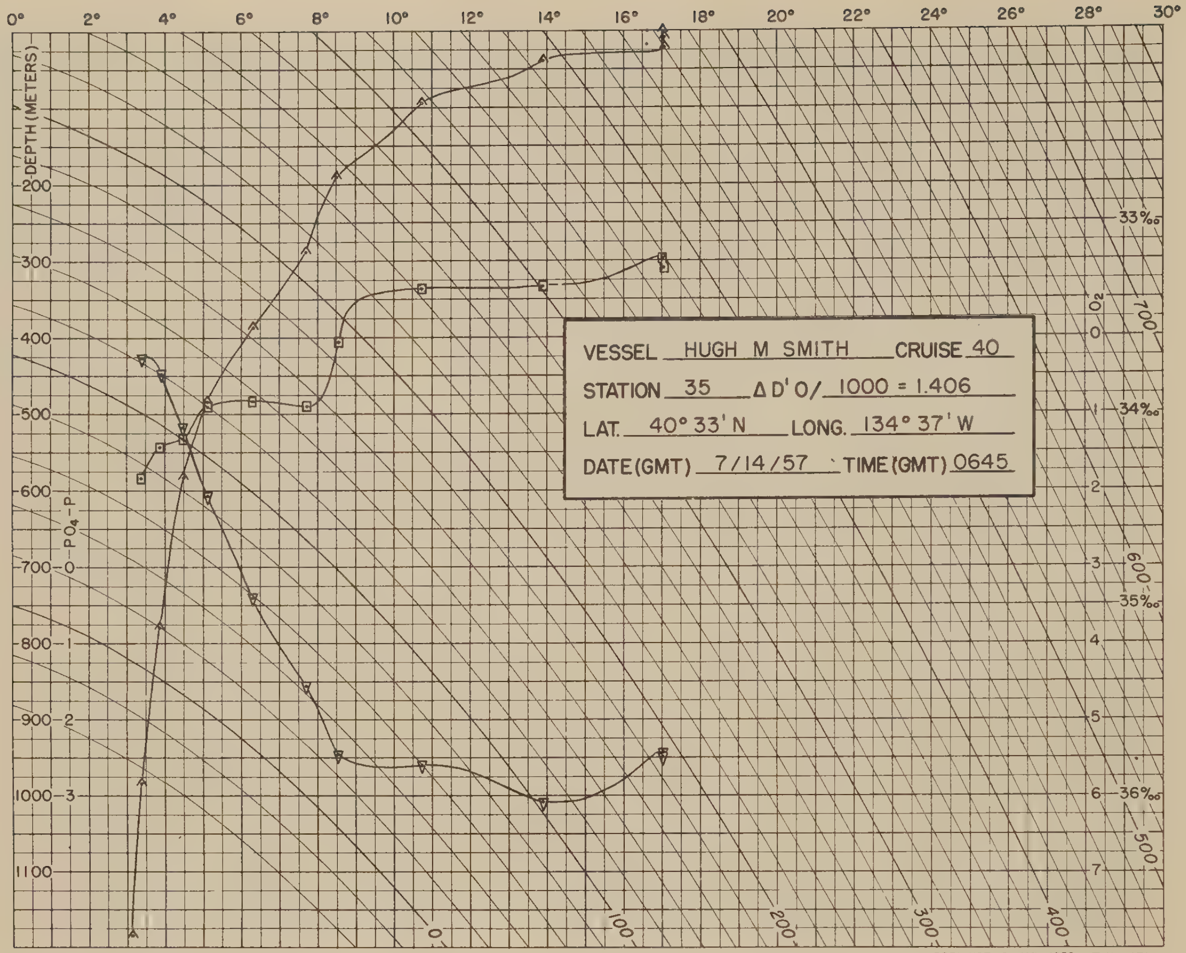
VESSEL HUGH M SMITH CRUISE 40
STATION 33 ΔD' 0/1000 = 1.382
LAT. 43° 02' N LONG. 136° 10' W
DATE (GMT) 7/13/57 TIME (GMT) 0557

POFI USFWS MAY 1956 T. NAKATA

Weather: 03, cloud coverage 8. Wind: 310°, 06 kt. Sea: 3-5 ft. Wire angle: 03°. BT slide: 93. Dry bulb: 61.3°F. Wet bulb: 58.9°F. Barometric pressure: 1002 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	15.07	32.84	361.9	5.80	NS
21	14.91	32.82	360.0	5.78	0.52
42	11.74	32.88	295.2	6.46	0.62
106	8.64	32.89	244.9	6.22	1.10
159	7.34	33.30	196.3	5.82	1.33
327	6.10	33.91	135.1	3.68	2.22
443	4.95	33.91	121.9	2.18	2.60
551	4.41	34.02	108.0	1.31	1.40
664	4.03	34.09	99.0	0.78	2.92
887	3.52	34.31	77.7	0.33	3.04
1102	3.08	34.36	69.9	0.30	3.71
1316	2.77	34.45	60.5	0.39	1.82*
1316					2.11*

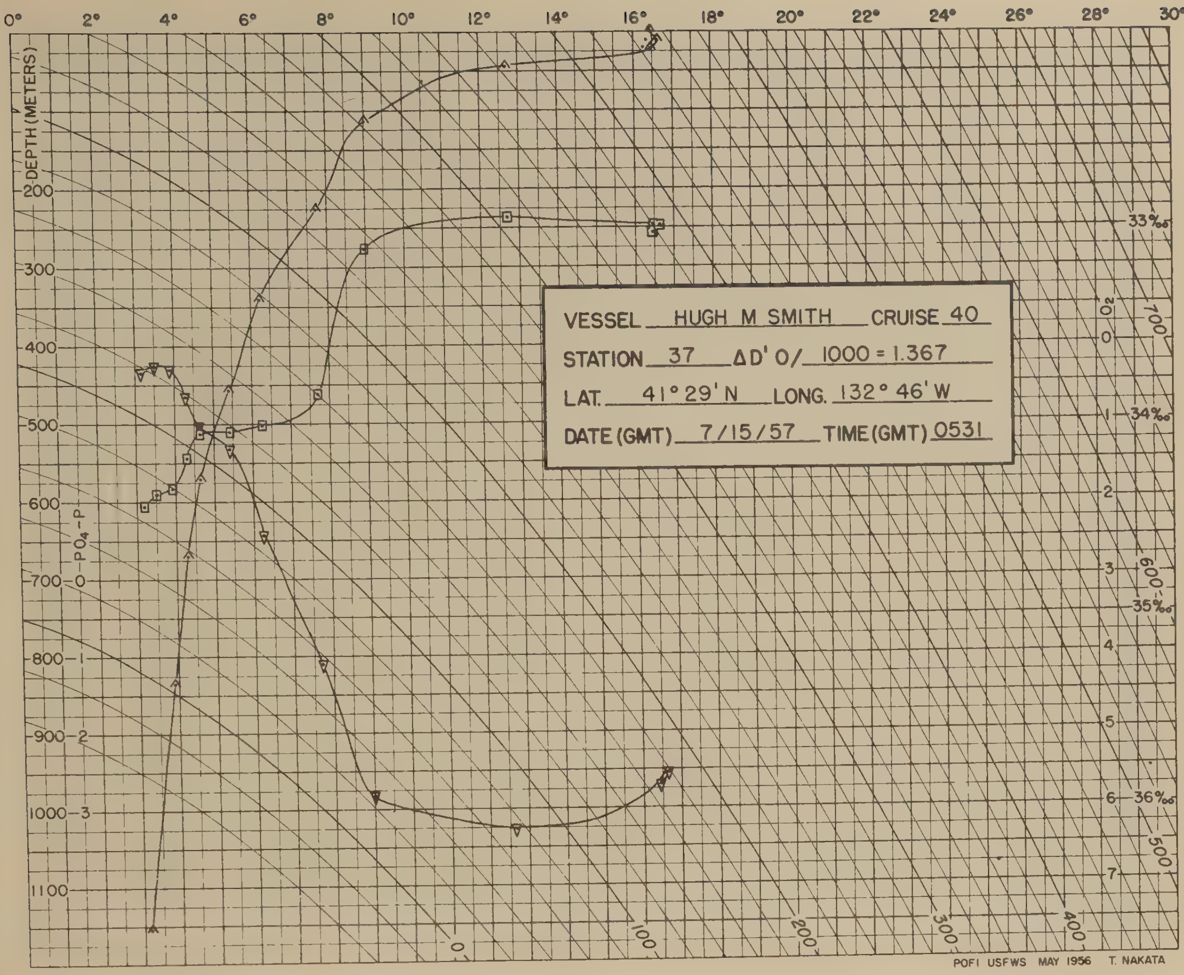
* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 4. Wind: 290°, 17 kt. Sea: 5-8 ft. Wire angle: 29°. BT slide: 104. Dry bulb: 61.8°F. Wet bulb: 59.2°F. Barometric pressure: 1016 mb.

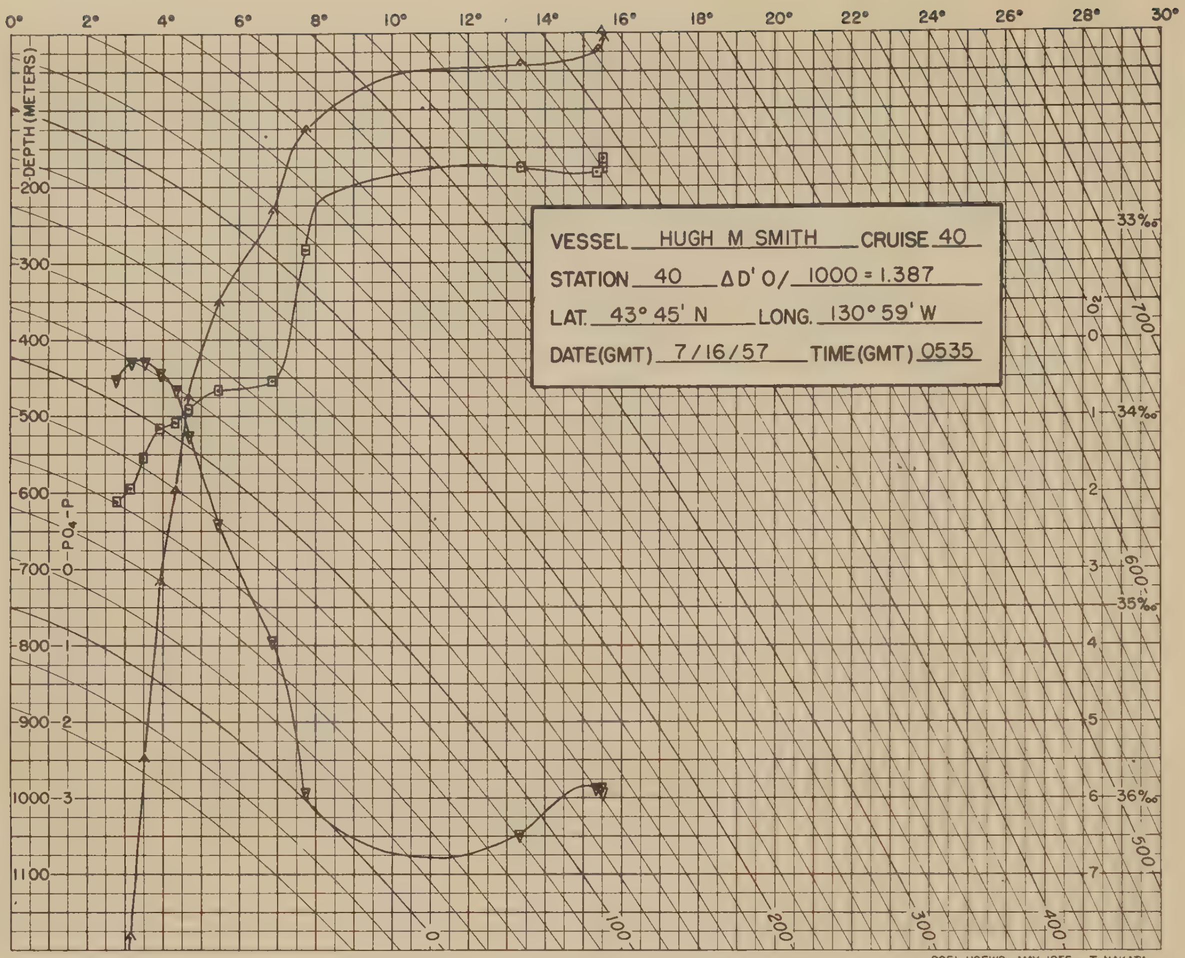
Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	17.02	33.24	374.4	5.49	0.50
8	17.02	33.19	378.2	5.48	0.51
21	17.04	33.24	375.0	5.44	0.48
39	13.89	33.33	302.2	6.06	0.48
95	10.74	33.35	243.3	5.60	0.75
190	8.55	33.62	189.3	5.45	1.19
287	7.70	33.96	152.0	4.54	1.57
387	6.32	33.93	136.4	3.40	1.89
484	5.11	33.96	120.0	2.08	1.79
582	4.47	34.13	100.4	1.18	2.56
779	3.85	34.18	90.5	0.48	3.16
983	3.38	34.34	74.1	0.27	3.21
1185	3.12	NG	-	NG	NG



VESSEL HUGH M SMITH CRUISE 40
STATION 37 ΔD' 0/ 1000 = 1.367
LAT. 41° 29' N LONG. 132° 46' W
DATE (GMT) 7/15/57 TIME (GMT) 0531

Weather: 02, cloud coverage 7. Wind: 280°, 10 kt. Sea: 3-5 ft. Wire angle: 17°. BT slide: 113. Dry bulb: 60.0°F. Wet bulb: 58.8°F. Barometric pressure: 1025 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	16.43	33.03	377.0	5.70	0.49
11	16.63	32.99	384.3	5.54	0.62
21	16.44	32.99	380.0	5.69	0.49
42	12.67	32.94	307.5	6.26	0.52
124	8.98	33.10	234.2	5.81	0.96
227	7.73	33.84	161.3	4.10	1.58
340	6.27	34.00	130.1	2.42	2.12
458	5.41	34.04	117.4	1.33	1.68
571	4.66	34.05	108.3	1.03	1.51
670	4.29	34.18	94.8	0.65	2.60
835	3.90	34.33	79.7	0.29	2.85
1000	3.50	34.36	73.7	0.27	2.94
1156	3.19	34.42	66.3	0.33	1.80

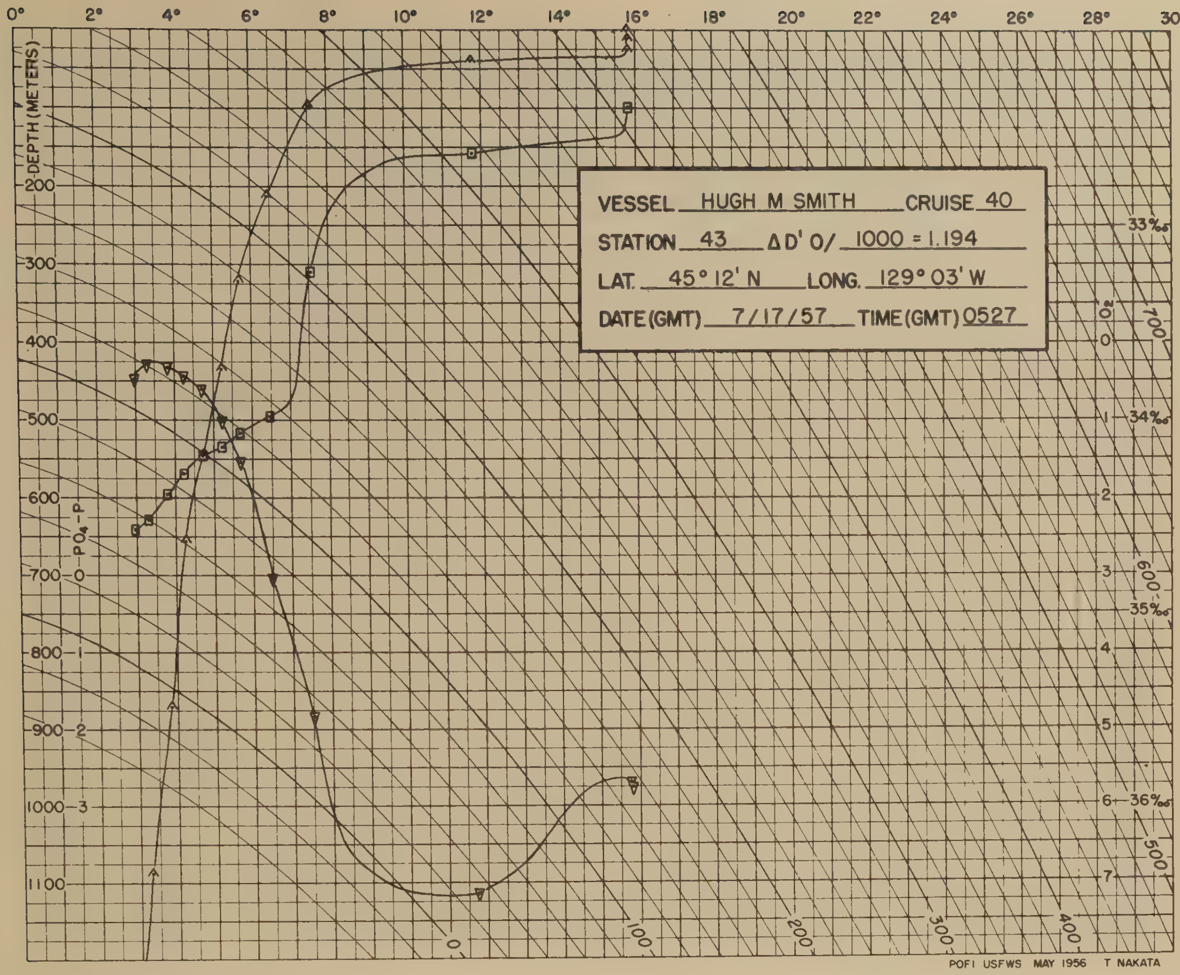


POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 4. Wind: 350°, 16 kt. Sea: 3-5 ft. Wire angle: 00°.
BT slide: 125. Dry bulb: 59.4°F. Wet bulb: 58.2°F. Barometric pressure: 1028 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O_2, ml. /L.	PO_4-P, µg at. /L.
0	15.49	32.66	383.9	5.88	0.57
11	15.50	32.70	381.0	5.91	0.51
21	15.39	32.72	377.2	5.88	0.40
42	13.35	32.70	338.0	6.47	0.58
127	7.74	33.13	214.3	5.94	1.02
233	6.88	33.82	151.7	3.94	1.63
353	5.44	33.87	130.2	2.41	2.46
479	4.68	33.96	115.5	1.25	1.43
599	4.36	34.04	105.9	0.66	1.47
719	3.93	34.07	99.5	0.43	3.00
951	3.53	34.22	84.6	0.29	3.33
1185	3.16	34.38	69.1	0.31	3.19
1403	2.80	34.45	60.8	0.52	1.40*
1403					1.45*

* Values of duplicate did not agree within 0.02 µg at. /L. tolerance so both are carried.



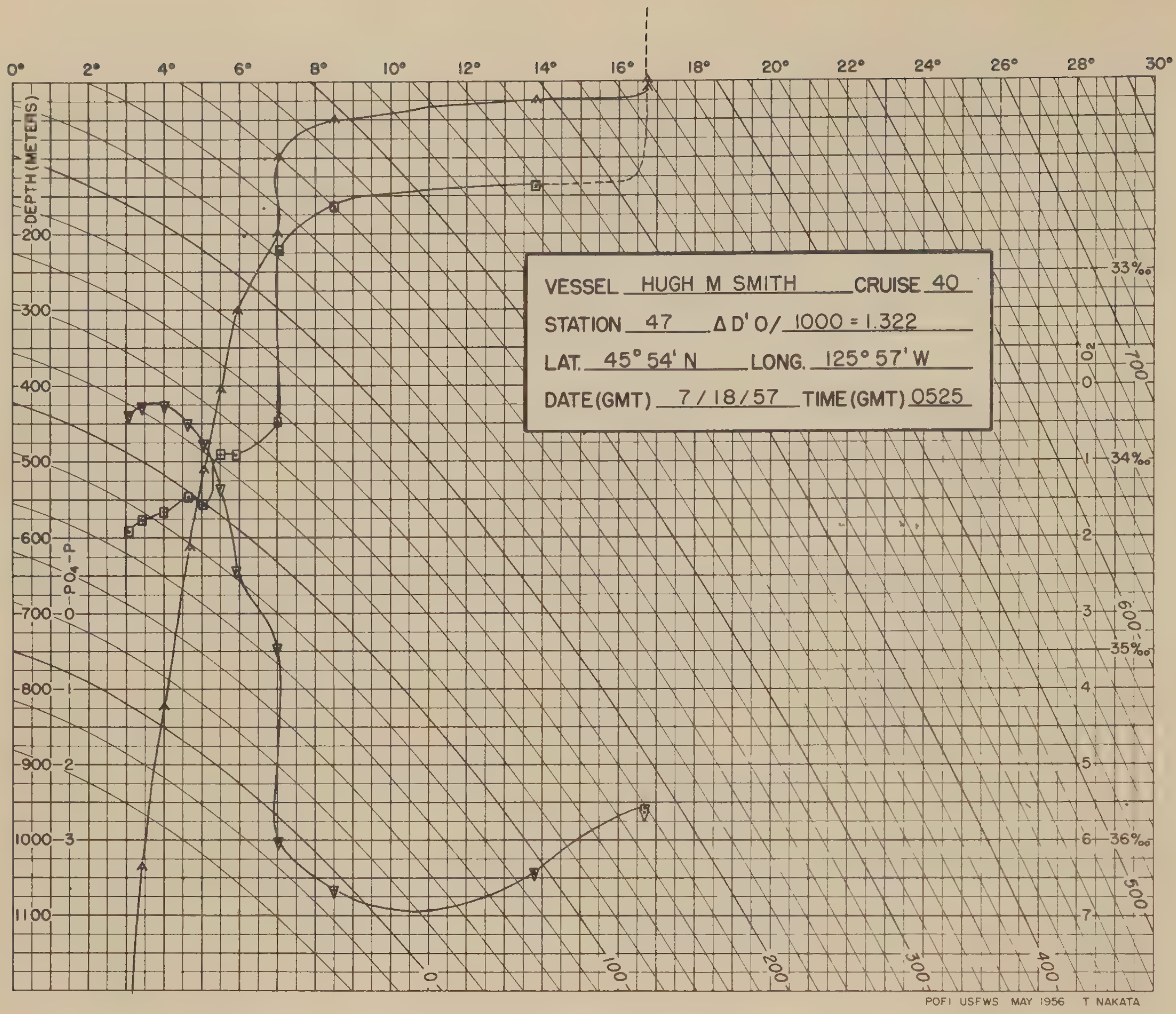
VESSEL HUGH M SMITH CRUISE 40
STATION 43 ΔD' 0/1000 = 1.194
LAT. 45° 12' N LONG. 129° 03' W
DATE (GMT) 7/17/57 TIME (GMT) 0527

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 6. Wind: 340°, 24 kt. Sea: 3-5 ft. Wire angle: 30°. BT slide: 134. Dry bulb: 58.8°F. Wet bulb: 57.6°F. Barometric pressure: 1029 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	15.78	NG	-	5.76	0.45
10	15.79	32.39	409.9	5.75	0.45
24	15.78	32.39	409.8	5.70	0.43
38	11.76	32.63	313.9	7.14	0.86
96	7.54	33.24	203.3	4.83	1.48
212	6.46	33.98	134.1	3.04	1.23
320	5.68	34.07	118.1	1.54	1.71
435	5.21	34.14	107.6	1.01	2.26
546	4.71	34.18	99.2	0.59	1.51
655	4.24	34.27	87.5	0.43	2.57
871	3.82	34.38	75.2	0.31	2.85
1086	3.30	34.51	60.7	0.28	2.94
1291	2.95	34.56	53.7	0.46	1.47*
1291					1.50*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.

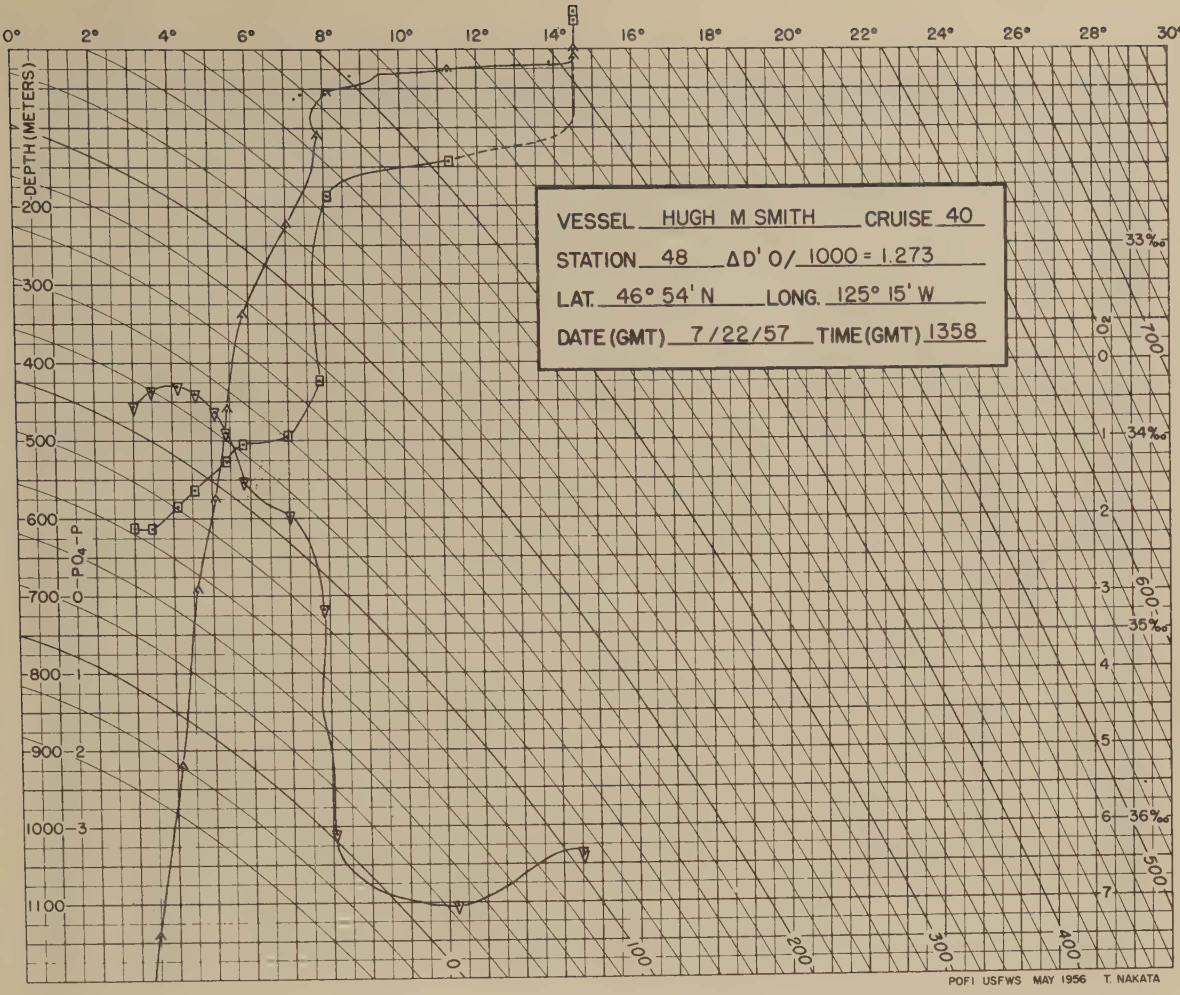


VESSEL HUGH M SMITH CRUISE 40
STATION 47 ΔD' 0/1000 = 1.322
LAT. 45° 54' N LONG. 125° 57' W
DATE (GMT) 7/18/57 TIME (GMT) 0525

Weather: 01, cloud coverage 4. Wind: 340°, 19 kt. Sea: 5-8 ft. Wire angle: 29°. BT slide: 145. Dry bulb: 60.7°F. Wet bulb: 58.3°F. Barometric pressure: 1021 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, μg at./L.
0	16.72	NG	-	5.62	0.47
10	16.72	NG	-	5.58	0.48
23	13.80	32.54	358.4	6.42	0.56
50	8.52	32.65	261.0	6.65	0.98
100	7.04	32.88	223.9	6.01	1.29
200	7.00	33.78	156.1	3.44	1.99
302	5.94	33.96	129.4	2.42	1.93
408	5.51	33.96	124.7	1.34	1.70
513	5.06	34.22 Q	99.8	0.77	1.84
617	4.66	34.18	98.6	0.49	3.08
825	4.02	34.27	85.3	0.25	2.79
1038	3.44	34.31	77.0	0.27	2.54
1242	3.10	34.36	70.1	0.36	2.37*
1242					2.23*

* Values of duplicate did not agree within 0.02 μg at./L. tolerance so both are carried.

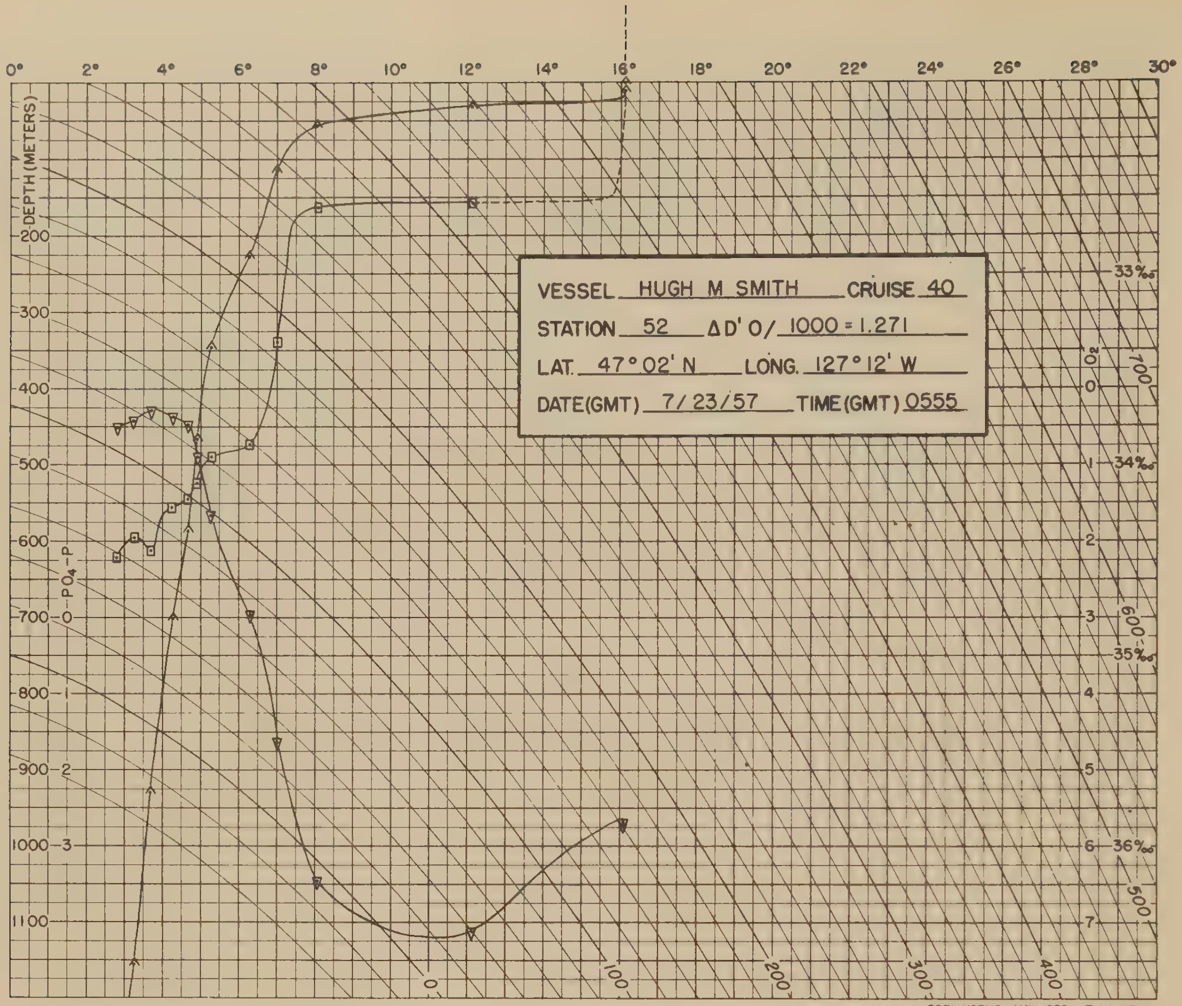


VESSEL HUGH M SMITH CRUISE 40
STATION 48 ΔD' 0/1000 = 1.273
LAT. 46° 54' N LONG. 125° 15' W
DATE (GMT) 7/22/57 TIME (GMT) 1358

POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 8. Wind: 320°, 07 kt. Sea: 1-3 ft. Wire angle: 16°. BT slide: 149. Dry bulb: 58.5°F. Wet bulb: 57.8°F. Barometric pressure: 1017 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	14.54	31.80	427.5	6.38	0.52
10	14.54	31.85	423.8	6.35	0.55
25	11.25	32.57	309.6	7.04	0.62
56	8.08	32.74	248.0	6.08	1.04
112	7.84	33.69	174.1	3.18	1.92
225	7.02	33.98	141.6	1.97	2.22
341	5.84	34.02	123.7	1.53	2.33
461	5.41	34.11	112.1	0.87	2.62
577	5.10	NG	-	0.63	2.53
694	4.60	34.25	92.8	0.41	2.85
920	4.15	34.34	81.2	0.31	2.83
1143	3.46	34.45	66.5	0.36	2.87
1353	3.02	34.45	62.6	0.56	2.11



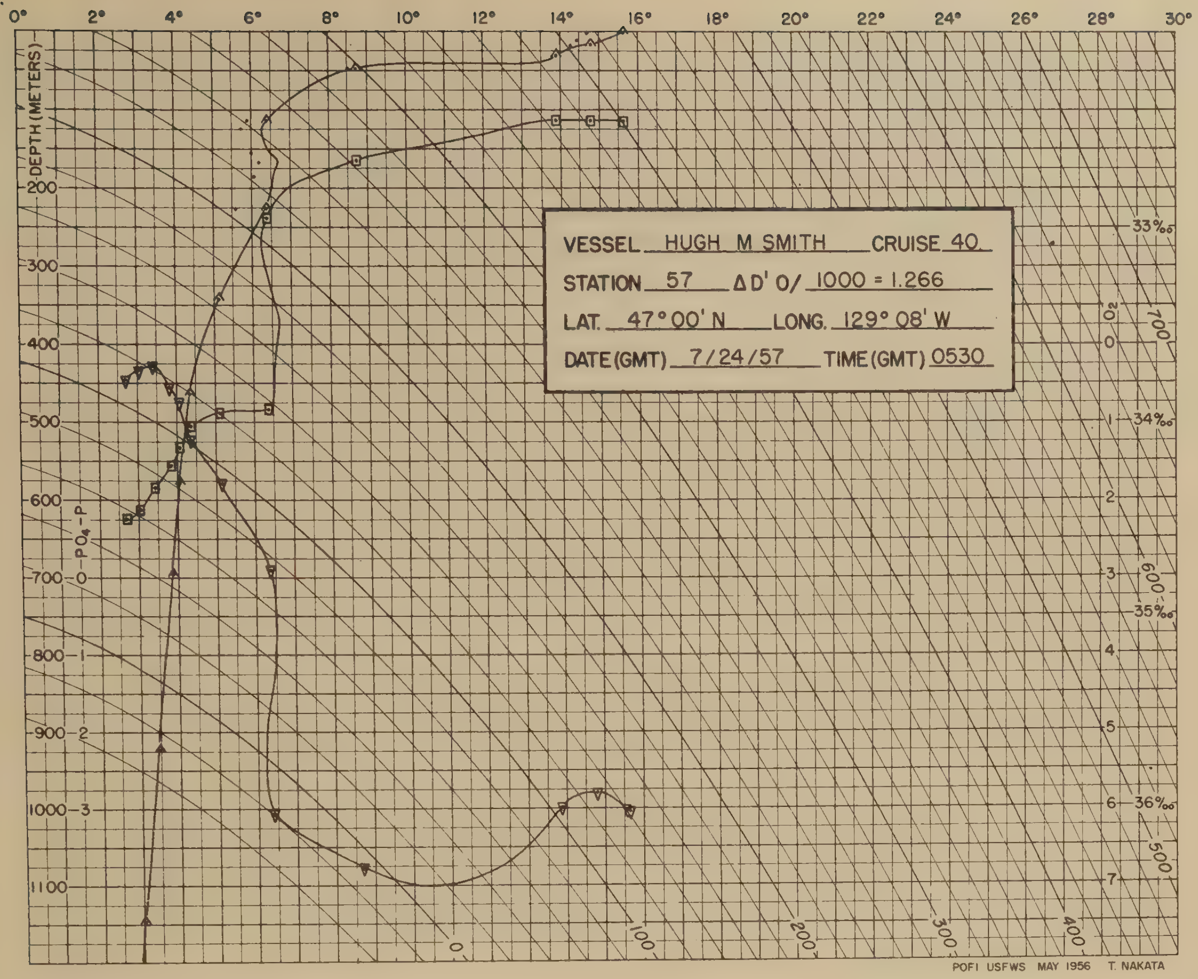
VESSEL HUGH M SMITH CRUISE 40
STATION 52 ΔD' 0/1000 = 1.271
LAT. 47° 02' N LONG. 127° 12' W
DATE (GMT) 7/23/57 TIME (GMT) 0555

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage not recorded. Wind: 260°, 15 kt. Sea: 1-3 ft. Wire angle: 15°. BT slide: 158. Dry bulb: 62.3°F. Wet bulb: 58.6°F. Barometric pressure: 1020 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	16.13	31.47	484.5	5.70	0.40
10	16.11	31.49	482.7	5.68	0.42
31	12.12	32.63	320.3	7.11	0.63
56	8.06	32.65	254.5	6.44	0.93
113	7.00	33.35	188.1	4.62	1.58
228	6.32	33.89	139.3	2.96	1.98
345	5.27	33.96	121.7	1.67	2.35
467	4.90	34.09	107.9	0.89	2.68
585	4.66	34.18	98.6	0.47	1.38
702	4.26	34.22	91.5	0.37	1.60
928	3.68	34.45 Q	68.5	0.28	2.85
1154	3.24	34.38	69.9	0.41	2.83
1362	2.78	34.49	57.6	0.50	1.66*
1362					1.31*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



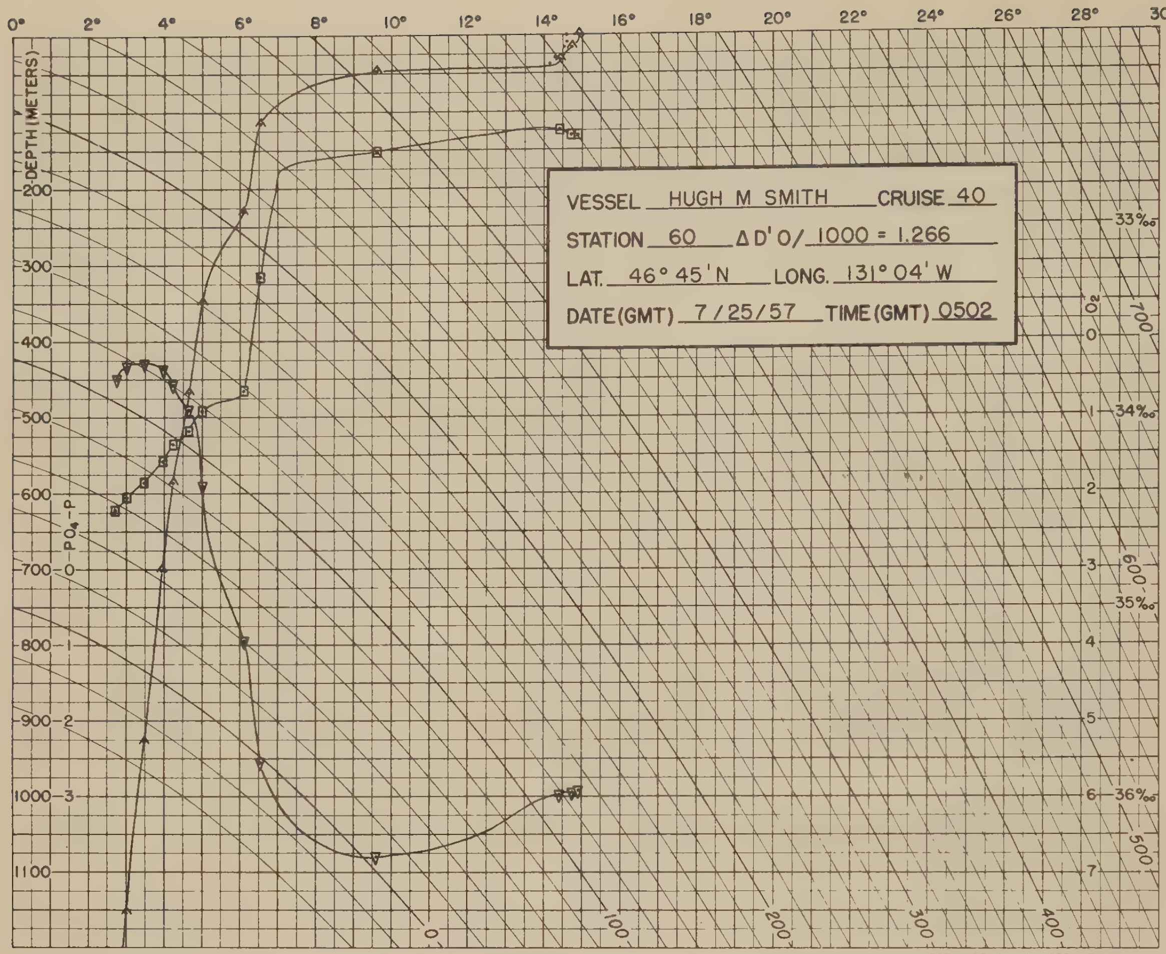
VESSEL HUGH M SMITH CRUISE 40
STATION 57 ΔD' 0/ 1000 = 1.266
LAT. 47° 00' N LONG. 129° 08' W
DATE (GMT) 7/24/57 TIME (GMT) 0530

POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 7. Wind: 280°, 06 kt. Sea: < 1 ft. Wire angle: 13°. BT slide: 167. Dry bulb: 59.8°F. Wet bulb: 58.1°F. Barometric pressure: 1026 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	15.64	32.45	402.3	6.03	0.44
15	14.80	32.45	385.0	5.79	0.51
30	13.88	32.45	366.8	5.98	0.56
46	8.71	32.66	263.0	6.76	0.86
112	6.42	32.95	210.7	6.06	1.30
226	6.40	33.93	137.2	2.90	1.97
342	5.14	33.95	121.1	1.79	2.11
463	4.37	34.02	107.5	1.21	2.57
578	4.06	34.13	96.2	0.72	1.30
696	3.83	34.22	87.2	0.53	2.22
922	3.41	34.33	75.2	0.29	2.77
1147	3.04	34.45	62.8	0.33	2.85
1360	2.71	34.49	57.1	0.45	1.93*
1360					1.79*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



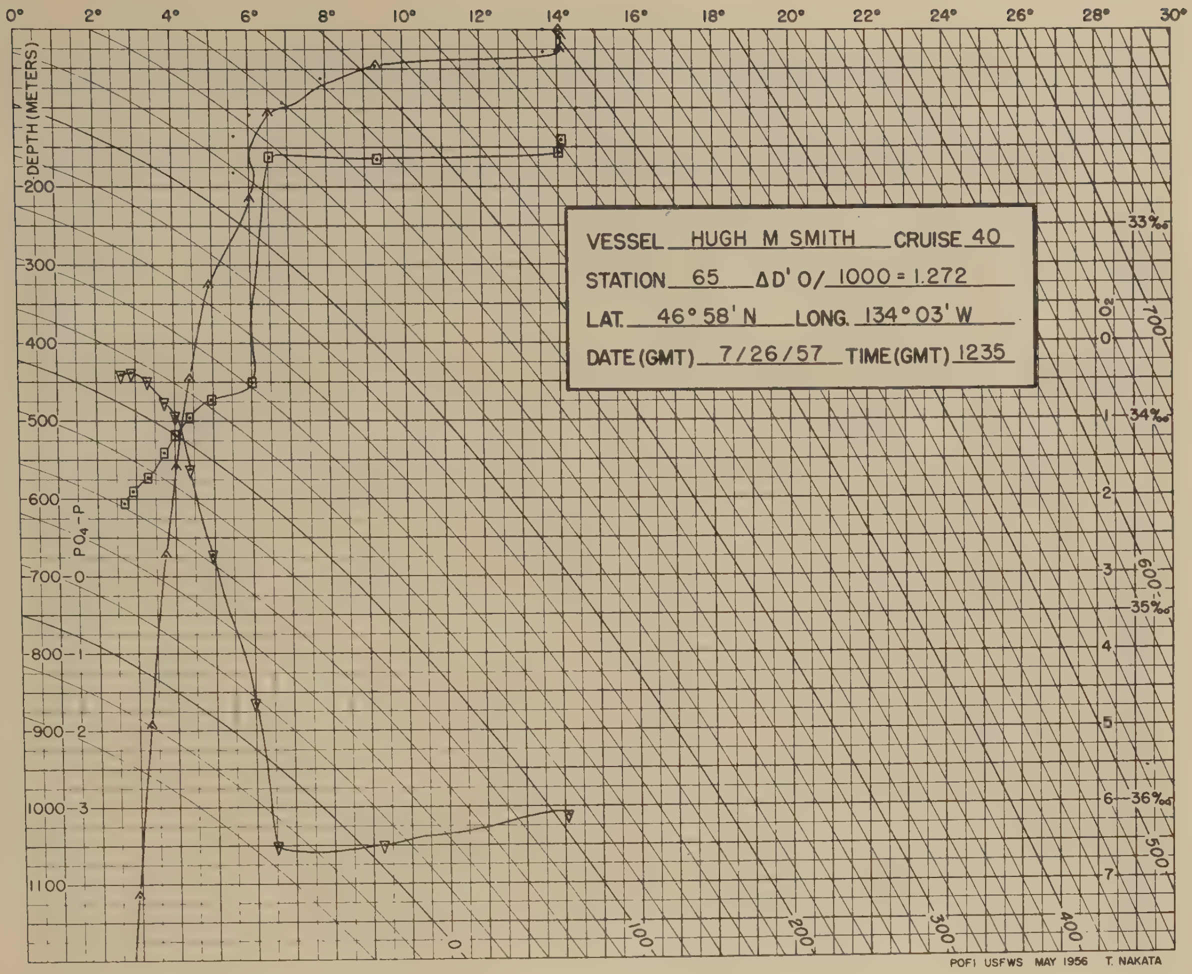
VESSEL HUGH M SMITH CRUISE 40
STATION 60 Δ D' 0/ 1000 = 1.266
LAT. 46° 45' N LONG. 131° 04' W
DATE (GMT) 7 / 25 / 57 TIME (GMT) 0502

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 8. Wind: 220°, 14 kt. Sea: 1-3 ft. Wire angle: 08°. BT slide: 178. Dry bulb: 61.8°F. Wet bulb: 60.2°F. Barometric pressure: 1020 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	14.92	32.52	382.2	5.93	0.47
16	14.77	32.52	379.1	5.95	0.58
31	14.42	32.49	374.3	5.98	0.54
47	9.62	32.61	280.3	6.80	0.83
115	6.56	33.26	189.1	5.54	1.38
230	6.11	33.87	138.2	3.95	1.79
348	5.00	33.96	118.8	1.89	2.11
469	4.66	34.07	106.9	0.90	2.61
585	4.25	34.14	97.4	0.59	1.17
700	3.97	34.23	87.8	0.36	2.81
928	3.46	34.34	74.9	0.31	2.82
1155	3.00	34.42	64.6	0.33	2.81
1369	2.72	34.49	57.1	0.51	1.38*
1369					1.49*

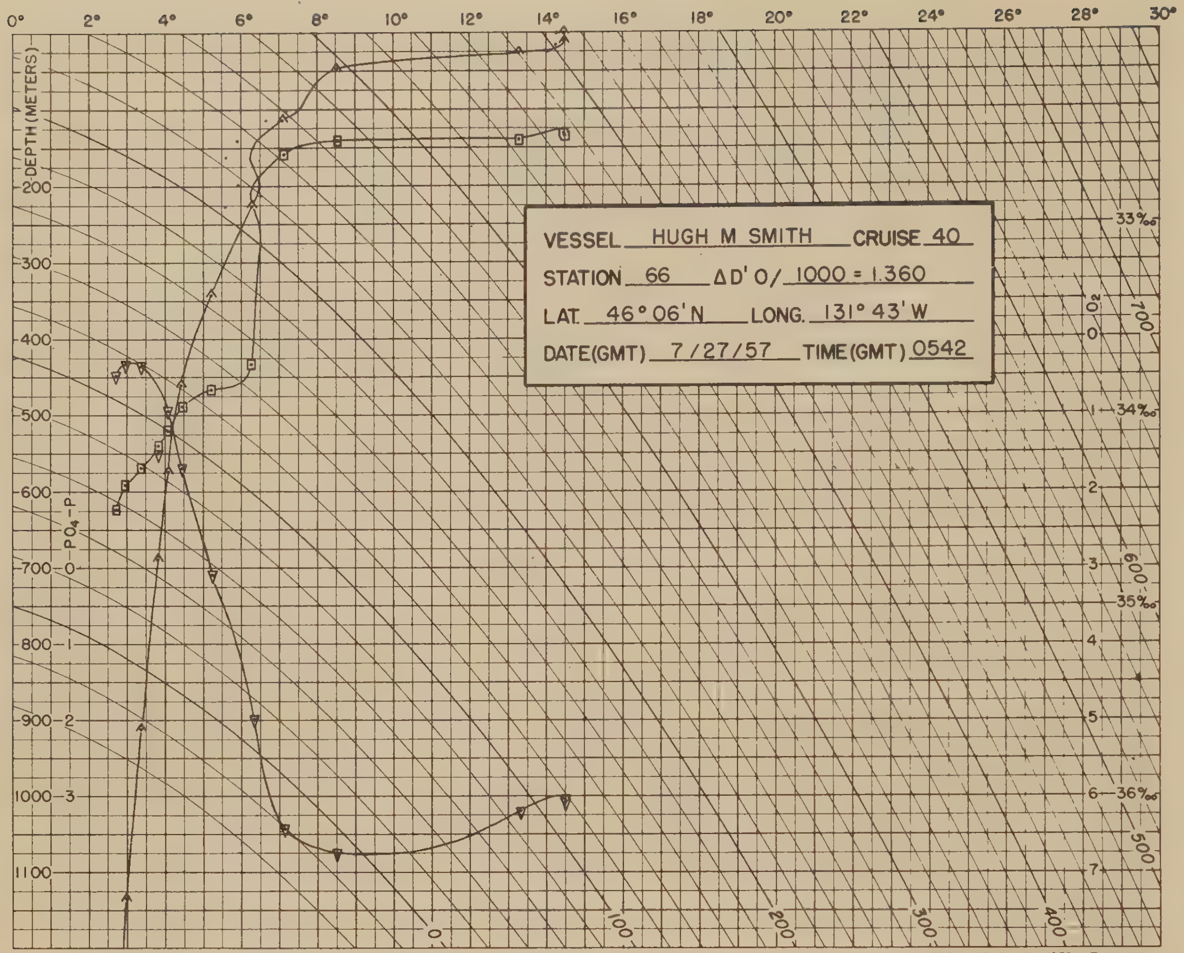
* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



VESSEL HUGH M SMITH CRUISE 40
STATION 65 ΔD' 0/1000 = 1.272
LAT. 46° 58' N LONG. 134° 03' W
DATE (GMT) 7/26/57 TIME (GMT) 1235

Weather: 63, cloud coverage 8. Wind: 250°, 20 kt. Sea: 3-5 ft. Wire angle: 19°. BT slide: 189. Dry bulb: 55.0°F. Wet bulb: 54.2°F. Barometric pressure: 1022 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	14.08	32.57	361.8	6.07	0.51
10	14.10	32.56	362.9	6.11	0.52
25	14.06	32.63	357.0	6.07	0.55
44	9.32	32.66	272.1	6.50 Q	0.71
108	6.57	32.65 Q	235.0	6.50	1.10
217	6.01	33.80	142.1	4.65	0.75
328	4.96	33.89	123.5	2.72	1.97
447	4.41	33.98	111.2	1.63	2.46
560	4.03	34.07	100.5	0.94	0.85
673	3.76	34.16	91.0	0.77	1.23
894	3.33	34.29	77.6	0.50	2.76
1114	2.92	34.36	68.6	0.38	1.51
1323	2.66	34.42	61.8	0.41	NS



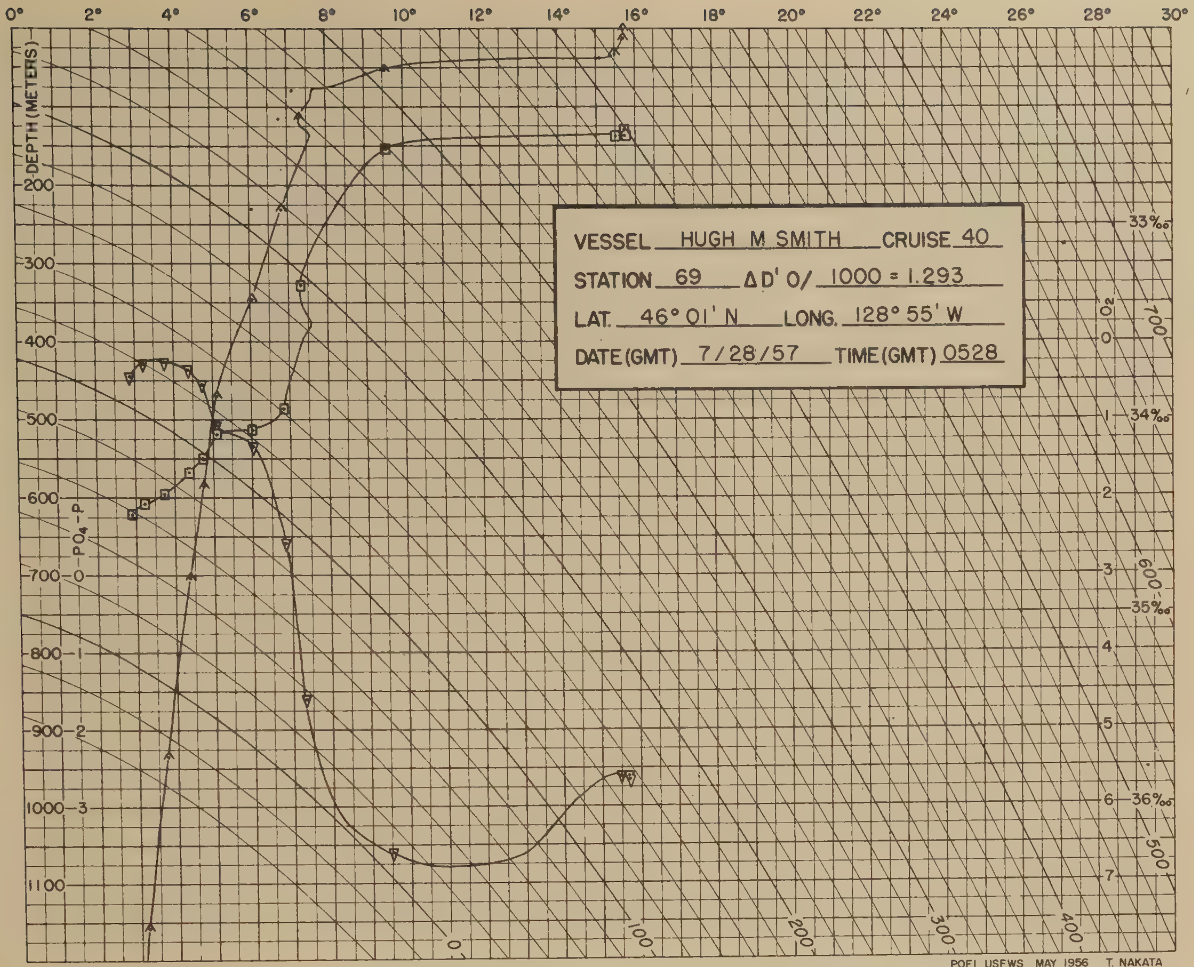
VESSEL HUGH M SMITH CRUISE 40
STATION 66 ΔD' 0/1000 = 1.360
LAT. 46° 06' N LONG. 131° 43' W
DATE(GMT) 7/27/57 TIME(GMT) 0542

POFI USFWS MAY 1956 T NAKATA

Weather: 53, cloud coverage not recorded. Wind: 250°, 20 kt. Sea: 5-8 ft. Wire angle: 21°, 18°. BT slide: 197. Dry bulb: 60.2°F. Wet bulb: 60.2°F. Barometric pressure: 1017 mb.

	Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
I	0	14.49	32.53	373.0	6.08	0.57
II	10	14.49	32.52	373.5	6.04	0.58
	26	13.32	32.55	348.4	6.20	0.49
	46	8.56	32.56	268.2	6.73	1.09
	113	7.12	32.63	243.4	6.42	1.27
	226	6.34	33.73	151.5	4.99	1.59
	341	5.22	33.86	128.8	3.09	1.89
	460	4.46	33.95	114.0	1.70	2.45
	574	4.08	34.08	100.1	0.94 P	1.25
	689	3.82	34.16	91.7	1.49	2.73
	911	3.38	34.27	79.3	0.36	1.21
	1134	2.98	34.36	68.8	0.32	2.82
	1348	2.74	34.49	57.3	0.46	1.38*
	1348					1.55*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.

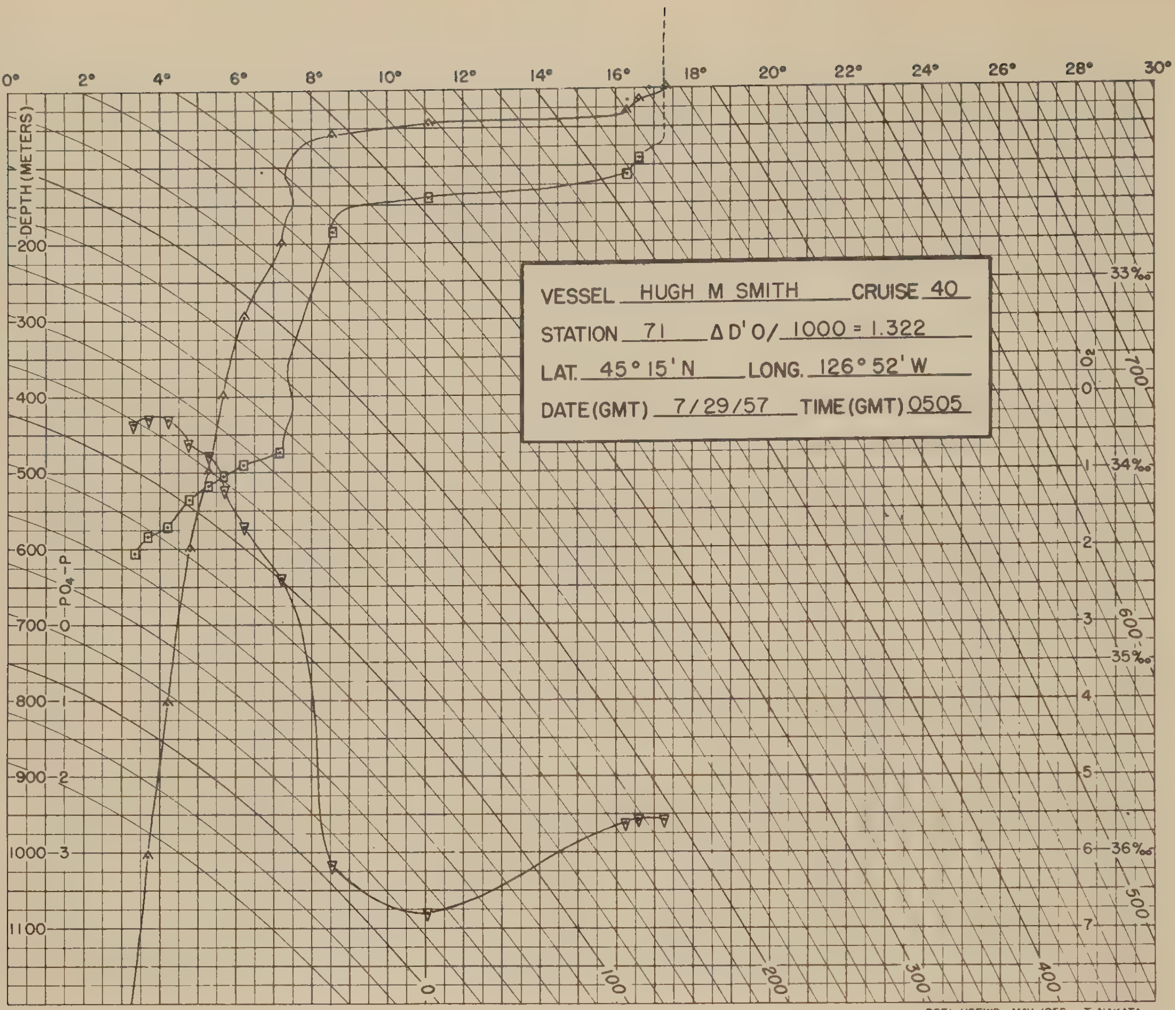


VESSEL HUGH M SMITH CRUISE 40
STATION 69 ΔD' 0/ 1000 = 1.293
LAT. 46° 01' N LONG. 128° 55' W
DATE (GMT) 7/28/57 TIME (GMT) 0528

POFI USFWS MAY 1956 T. NAKATA

Weather: 40, cloud coverage 8. Wind: 220°, 18 kt. Sea: 3-5 ft. Wire angle: 06°, 11°. BT slide: 204. Dry bulb: 62.0°F. Wet bulb: 62.0°F. Barometric pressure: 1019 mb.

	Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
	0	15.71	32.52	398.9	5.62	0.68
	10	15.72	32.54	397.5	5.61	0.53
	31	15.48	32.54	392.3	5.61	0.40
I	52	9.54	32.61	279.1	6.60	0.95
II	114	7.32	33.34	193.1	4.62	1.93
	230	6.84	33.95	141.4	2.59	2.14
	347	6.04	34.05	123.8	1.35	2.40
	470	5.10	34.07	111.5	1.07	2.87
	587	4.77	34.20	98.2	0.54	1.54
	704	4.40	34.27	89.2	0.35	3.30
	933	3.76	34.38	74.6	0.26	3.14
	1159	3.22	34.43	66.0	0.29	2.36
	1373	2.88	34.49	58.4	0.44	2.16



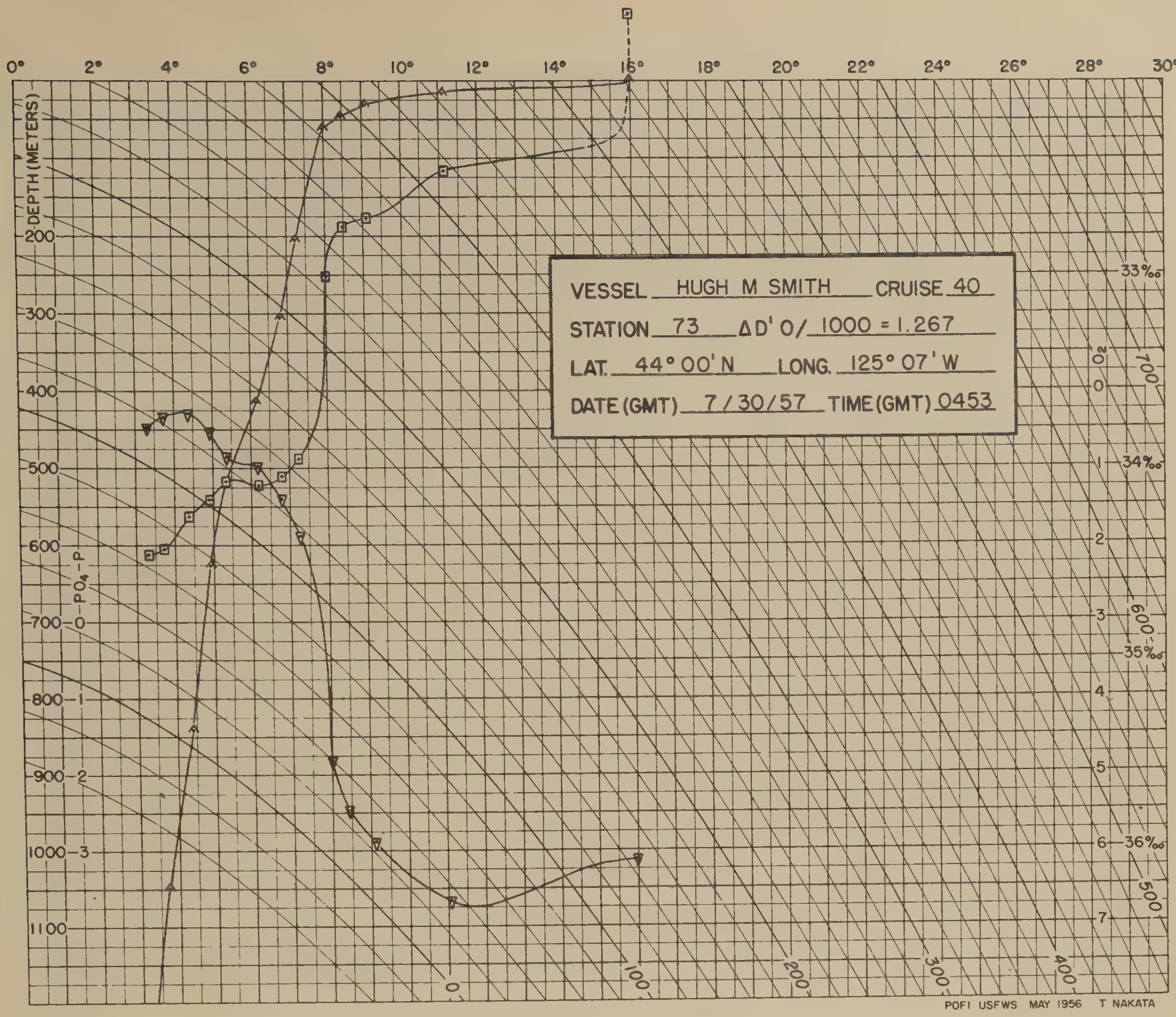
VESSEL HUGH M SMITH CRUISE 40
STATION 71 Δ D' 0/ 1000 = 1.322
LAT. 45° 15' N LONG. 126° 52' W
DATE (GMT) 7/29/57 TIME (GMT) 0505

POFI USFWS MAY 1956 T NAKATA

Weather: 20, cloud coverage 8. Wind: 330°, 10 kt. Sea: 1-3 ft. Wire angle: 25°. BT slide: 212. Dry bulb: 62.0°F. Wet bulb: 62.0°F. Barometric pressure: 1017 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	17.27	31.36	517.6	5.57	0.57
15	16.60	32.36	429.7	5.57	0.54
30	16.26	32.44	416.2	5.62	0.57
44	11.06	32.56	307.2	6.80	0.74
58	8.57	32.74	255.0	6.17	1.02
200	7.22	33.89	150.9	2.38	2.36
296	6.26	33.96	133.3	1.71	2.58
400	5.70	34.02	122.0	1.23	2.97
499	5.31	34.07	114.0	0.79	1.41
601	4.78	34.14	102.8	0.61	2.76
805	4.22	34.29	85.8	0.29	3.42
1005	3.72	34.34	77.3	0.29	1.57
1210	3.26	34.43	66.3	0.36	1.94*
1210					1.80*

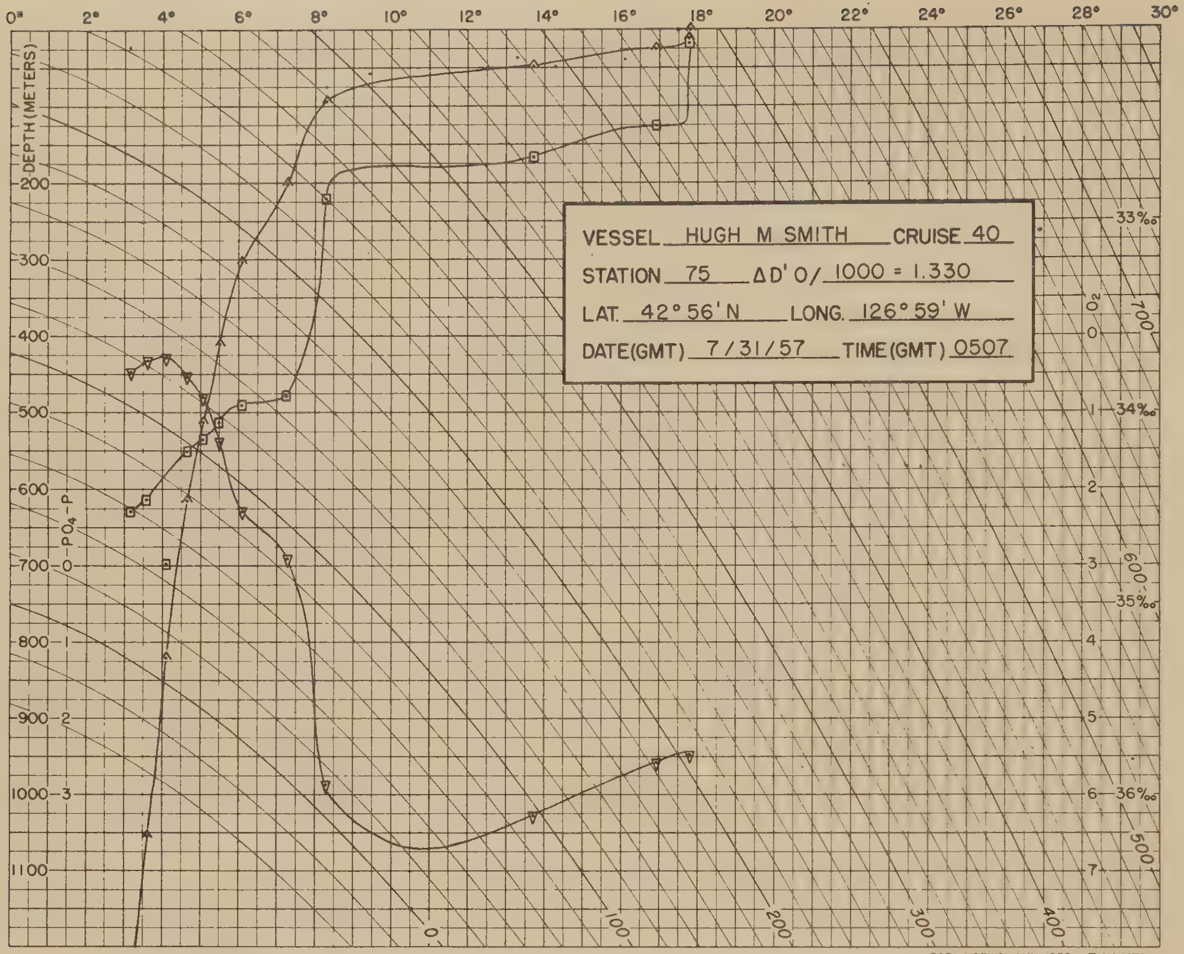
* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



Weather: 02, cloud coverage 7. Wind: 330°, 17 kt. Sea: 1-3 ft. Wire angle: 23°. BT slide: 221. Dry bulb: 62.6°F. Wet bulb: 62.0°F. Barometric pressure: 1018 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	15.98	31.66	467.5	6.13	0.64
15	11.10	32.46	315.2	6.66	0.95
30	9.08	32.70	265.3	5.89	1.18
45	8.46	32.75	252.8	5.46	1.56
60	8.00	33.01	226.9	4.81	1.69
205	7.26	33.95	146.9	1.88	1.99
306	6.80	34.04	134.0	1.40	2.06
414	6.18	34.09	122.5	0.98	2.37
517	5.35	34.07	114.4	0.85	1.95
626	4.92	34.16	102.9	0.53	2.39
840	4.38	34.25	90.4	0.29	3.18
1049	3.72	34.42	71.3	0.33	2.12
1261	3.32	34.45	65.4	0.46	2.22*
1261					2.34*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



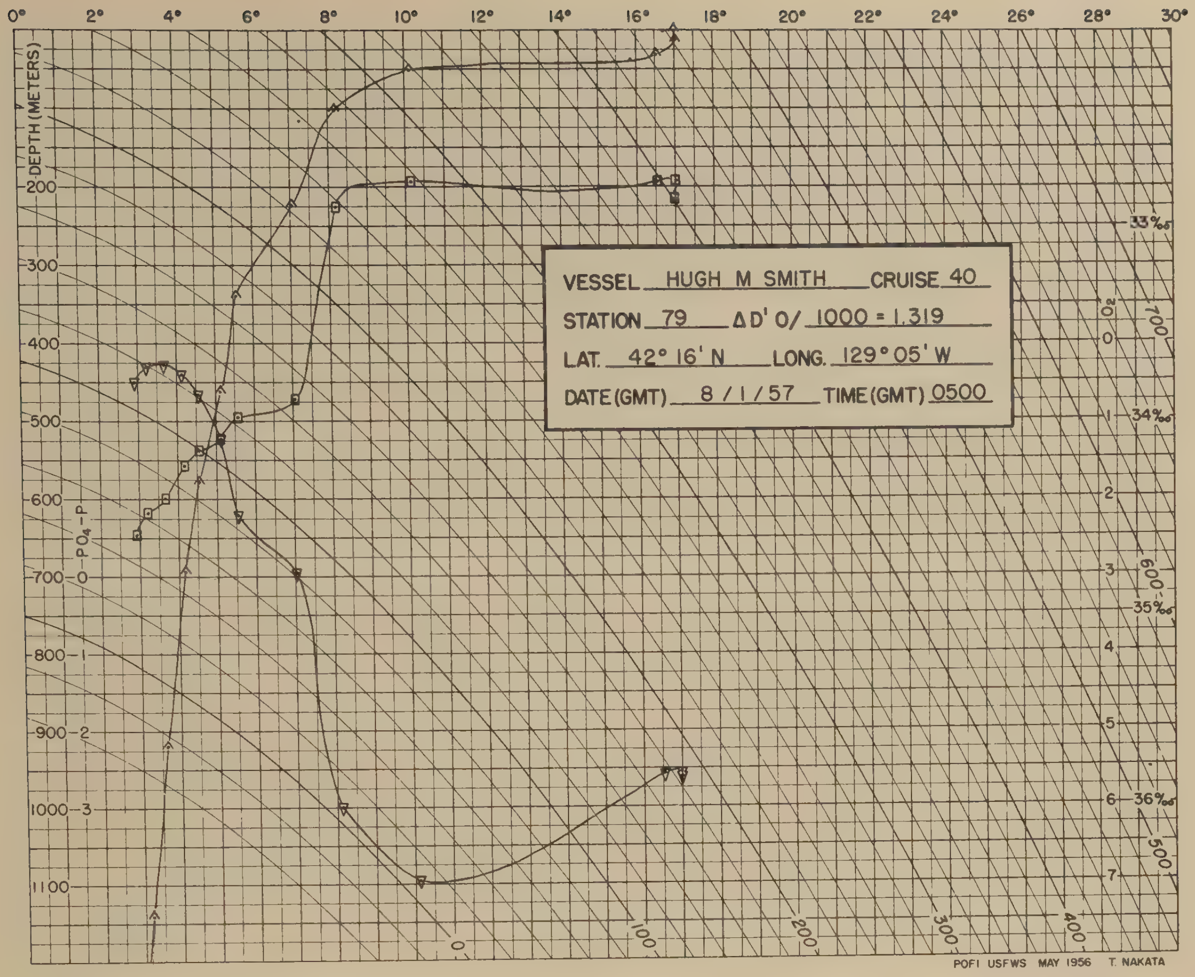
VESSEL HUGH M SMITH CRUISE 40
STATION 75 ΔD' 0/1000 = 1.330
LAT. 42° 56' N LONG. 126° 59' W
DATE(GMT) 7/31/57 TIME(GMT) 0507

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 2. Wind: 330°, 14 kt. Sea: 1-3 ft. Wire angle: 27°, 29°. BT slide: 230, Dry bulb: 62.9°F. Wet bulb: 60.7°F. Barometric pressure: 1021 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	17.80	32.07	477.5	5.47	0.44
10	17.78	32.07	477.0	5.46	0.43
23	16.93	32.50	426.5	5.57	0.50
46	13.73	32.66	348.2	6.28	0.53
92	8.30	32.88	241.0	5.86	1.44
201	7.30	33.91	150.3	2.89	2.42
303	6.10	33.96	131.3	2.28	2.67
409	5.53	34.05	118.0	1.39	3.04
512	5.08	34.14	106.0	0.80	3.00
614	4.66	34.20	97.2	0.53	3.40
I 819	4.10	34.79	47.0	0.27	3.58
II 1053	3.61	34.45	68.0	0.33	2.28
1254	3.18	34.51	59.5	0.47	3.14*
1254					2.72*

* Values of duplicate did not agree within 0.02 µg at. /L. tolerance so both are carried.

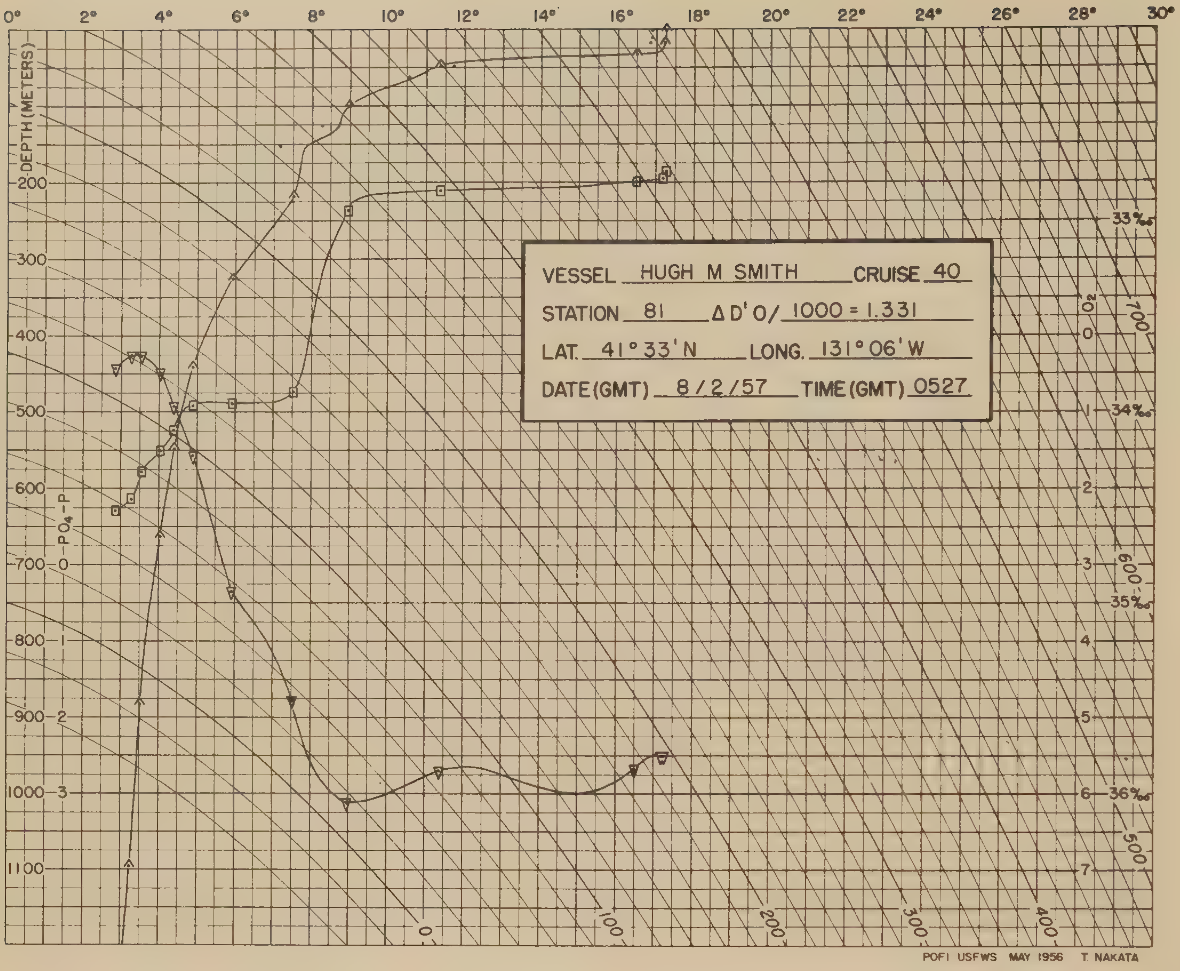


VESSEL HUGH M SMITH CRUISE 40
STATION 79 ΔD' 0/ 1000 = 1.319
LAT. 42° 16' N LONG. 129° 05' W
DATE (GMT) 8 / 1 / 57 TIME (GMT) 0500

Weather: 02, cloud coverage 5. Wind: 000°, 17 kt. Sea: 1-3 ft. Wire angle: 10°, 15°. BT slide: 238. Dry bulb: 62.5°F. Wet bulb: 61.0°F. Barometric pressure: 1026 mb.

	Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
	0	16.97	32.86	401.1	5.61	0.69
	10	17.00	32.77	408.3	5.56	0.62
I	31	16.54	32.77	398.3	5.58	0.49
II	51	10.12	32.77	276.3	6.96	0.87
	102	8.15	32.90	237.3	5.99	1.22
	225	7.04	33.89	148.6	2.95	2.21
	341	5.56	33.98	123.5	2.20	2.78
	462	5.14	34.09	110.5	1.23	3.08
	578	4.56	34.16	99.2	0.66	2.80
	693	4.16	34.23	89.7	0.40	2.81
	919	3.66	34.40	72.1	0.27	3.37
	1141	3.22	34.47	62.9	0.32	3.28
	1353	2.92	34.58	52.0	0.50	1.40*
	1353					1.65*

* Values of duplicate did not agree within 0.02 µg at. /L. tolerance so both are carried.



VESSEL HUGH M SMITH CRUISE 40

STATION 81 Δ D' 0/ 1000 = 1.331

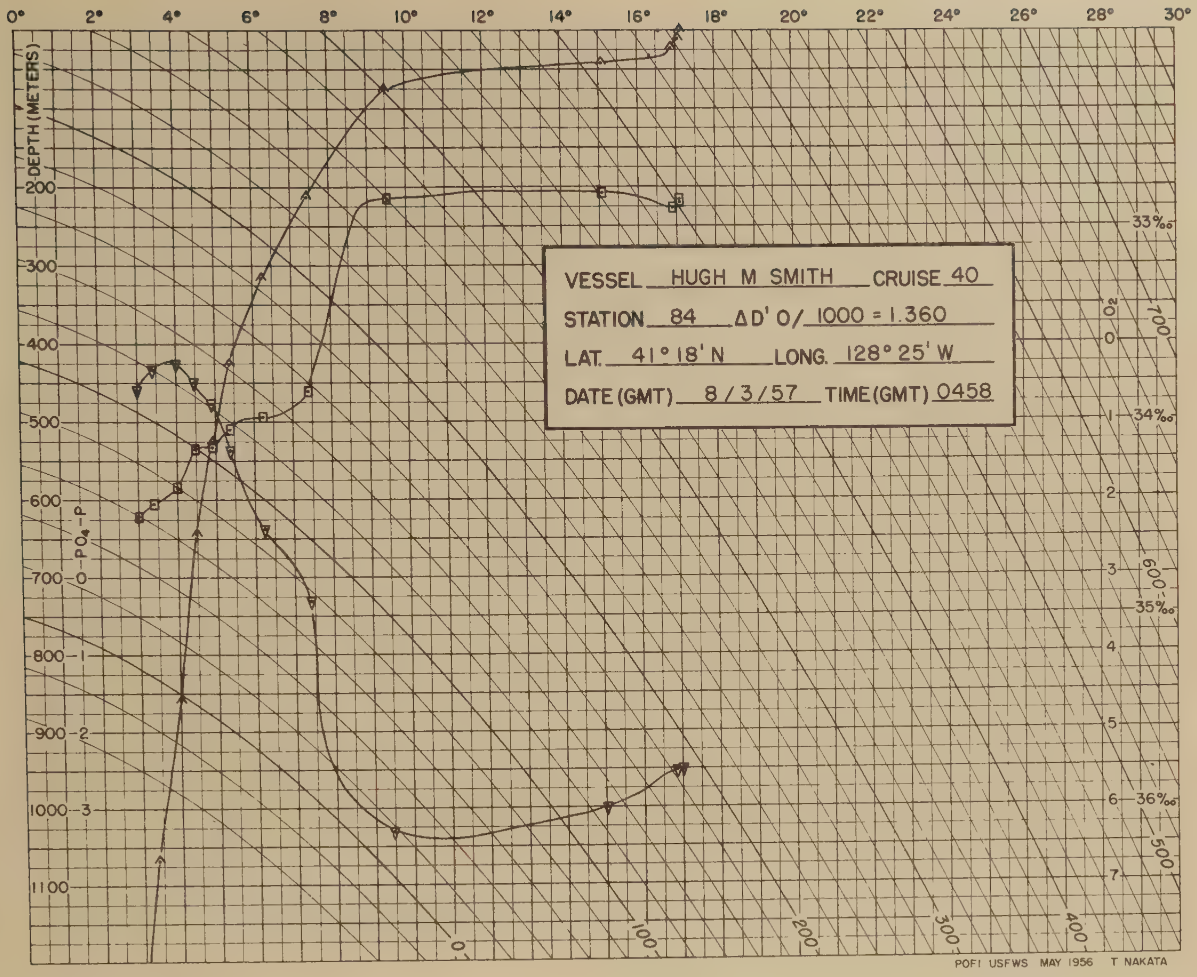
LAT. 41° 33' N LONG. 131° 06' W

DATE (GMT) 8 / 2 / 57 TIME (GMT) 0527

Weather: 02, cloud coverage 5. Wind: 330°, 10 kt. Sea: 1-3 ft. Wire angle: 00°. BT slide: 247. Dry bulb: 62.8°F. Wet bulb: 60.2°F. Barometric pressure: 1028 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O_2, ml./L.	PO_4-P, µg at./L.
0	17.25	32.74	416.4	5.51	0.57
15	17.20	32.77	413.0	5.50	0.57
31	16.48	32.79	395.7	5.68	1.76
47	11.36	32.84	291.5	5.69	0.71
100	8.95	32.94	245.7	6.11	1.07
217	7.54	33.89	155.1	4.77	1.64
325	5.93	33.95	130.0	3.34	2.13
440	4.88	33.96	117.6	1.57	1.96
548	4.40	34.09	102.7	0.92	1.72
661	4.04	34.20	90.9	0.48	3.16
882	3.54	34.31	77.9	0.26	3.08
1095	3.24	34.45	64.6	0.26	1.82
1309	2.85	34.52	56.0	0.42	2.53*
1309					2.93*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.

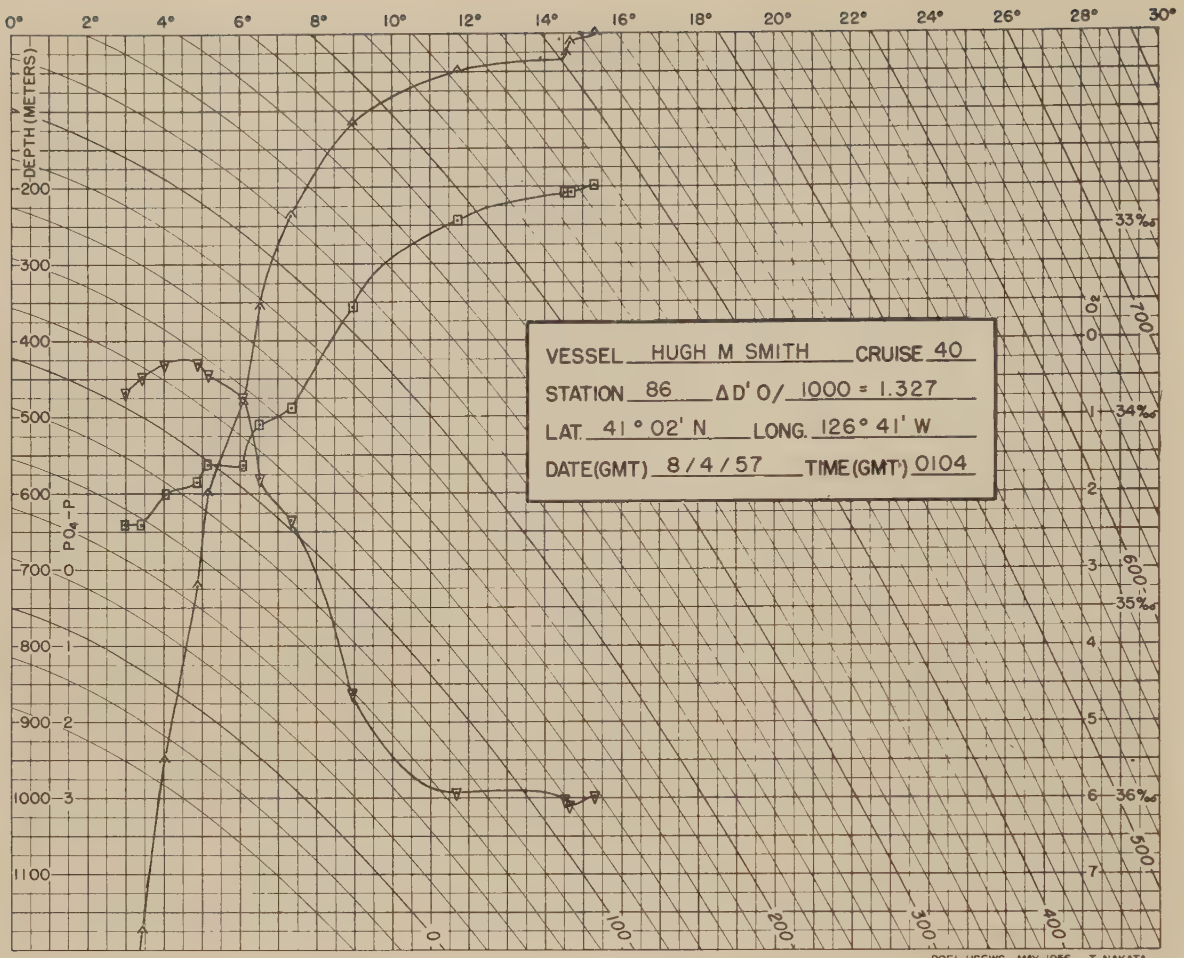


VESSEL HUGH M SMITH CRUISE 40
STATION 84 ΔD' 0/1000 = 1.360
LAT. 41° 18' N LONG. 128° 25' W
DATE (GMT) 8/3/57 TIME (GMT) 0458

Weather: 02, cloud coverage 8. Wind: 280°, 12 kt. Sea: < 1 ft. Wire angle: 13°. BT slide: 256. Dry bulb: 62.8°F. Wet bulb: 61.3°F. Barometric pressure: 1021 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	17.06	32.86	403.4	5.49	0.55
10	17.04	32.88	401.4	5.49	0.55
21	16.88	32.90	396.3	5.51	0.58
40	15.03	32.83	361.8	6.00	0.62
76	9.48	32.86	259.5	6.30	0.93
212	7.41	33.84	157.1	3.30	1.90
317	6.26	33.98	131.9	2.38	1.57
427	5.39	34.04	117.0	1.37	1.77
533	4.92	34.11	106.6	0.77	1.76
644	4.47	34.14	99.6	0.49	2.35
860	4.00	34.34	79.9	0.26	2.48
1068	3.40	34.42	68.3	0.34	2.01
1278	3.00	34.49	59.4	0.58	2.13*
1278					1.80*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



VESSEL HUGH M SMITH CRUISE 40

STATION 86 ΔD' 0/1000 = 1.327

LAT. 41° 02' N LONG. 126° 41' W

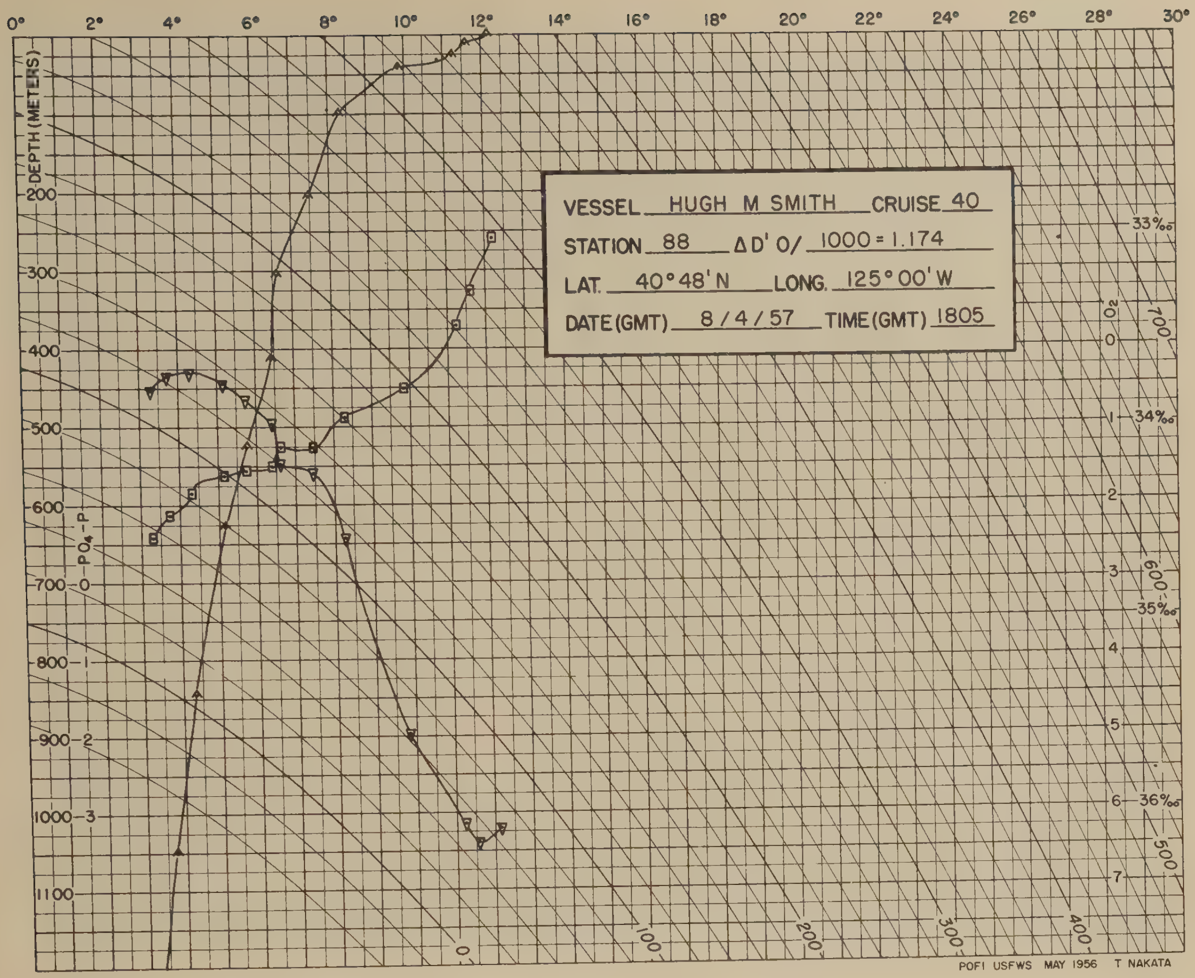
DATE (GMT) 8/4/57 TIME (GMT) 0104

POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 6. Wind: 240°, 10 kt. Sea: 3-5 ft. Wire angle: 03°. BT slide: 262. Dry bulb: 63.5°F. Wet bulb: 62.9°F. Barometric pressure: 1015 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	15.28	32.79	370.0	5.98	0.60
11	14.66	32.83	354.2	6.08	0.60
27	14.55	32.83	352.0	6.02	0.64
48	11.71	32.97	288.1	5.93	0.99
117	8.95	33.42	210.0	4.63	1.75
236	7.36	33.95	148.0	2.34	2.52
356	6.54	34.04	130.8	1.79	2.64
481	6.08	34.25	109.3	0.74	3.20
601	5.18	34.25	98.8	0.43	1.68
721	4.89	34.34	88.9	0.29	3.05
952	4.04	34.40	75.8	0.30	3.50
1177	3.42	34.56	58.0	0.47	2.53
1386	2.99	34.56	53.9	0.66	2.38*
1386					1.83*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried



VESSEL HUGH M SMITH CRUISE 40

STATION 88 ΔD' 0/ 1000 = 1.174

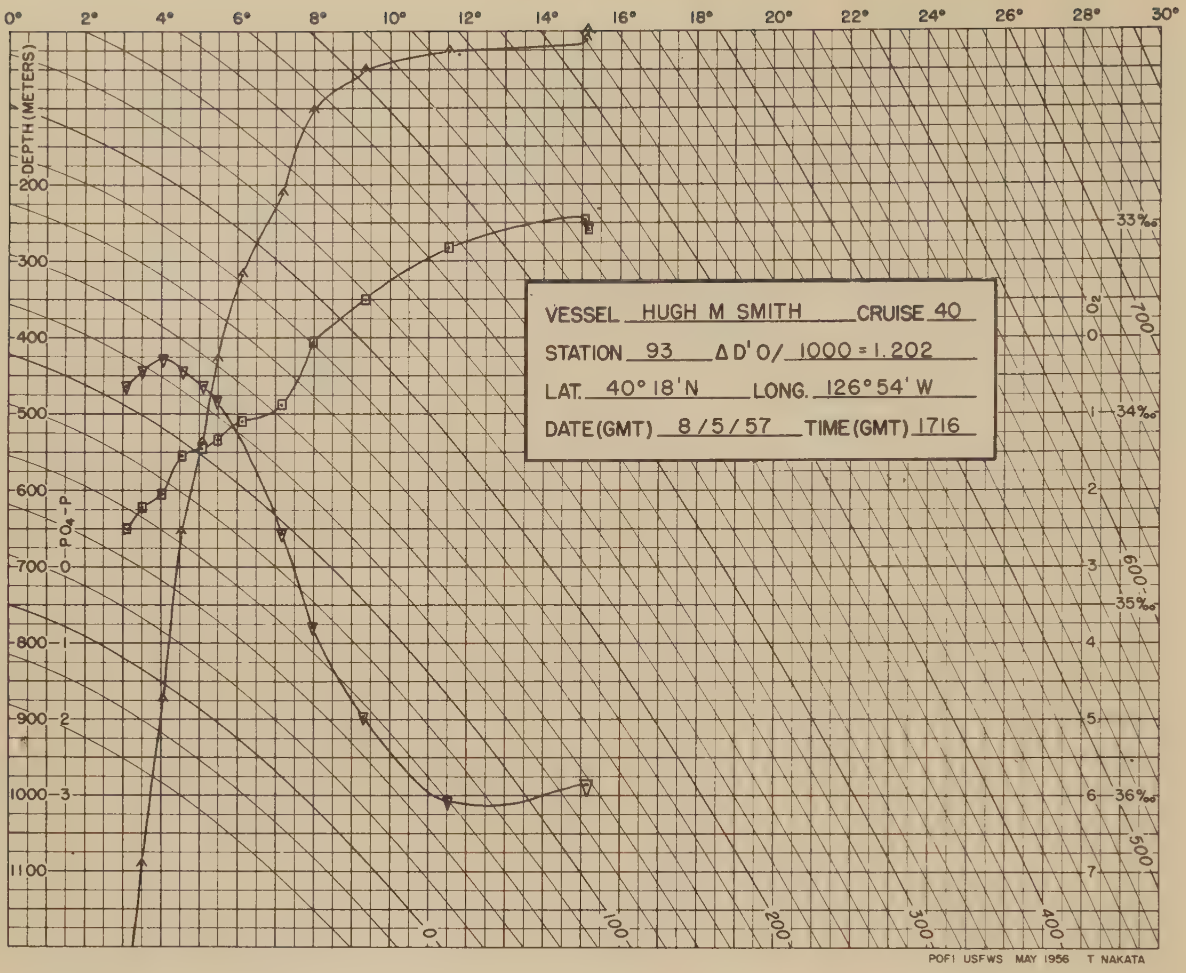
LAT. 40°48'N LONG. 125°00'W

DATE (GMT) 8/4/57 TIME (GMT) 1805

Weather: 02, cloud coverage 6. Wind: 160°, 13 kt. Sea: 1-3 ft. Wire angle: 17°.
BT slide: 268. Dry bulb: 60.8°F. Wet bulb: 57.3°F. Barometric pressure: 1014 mb.

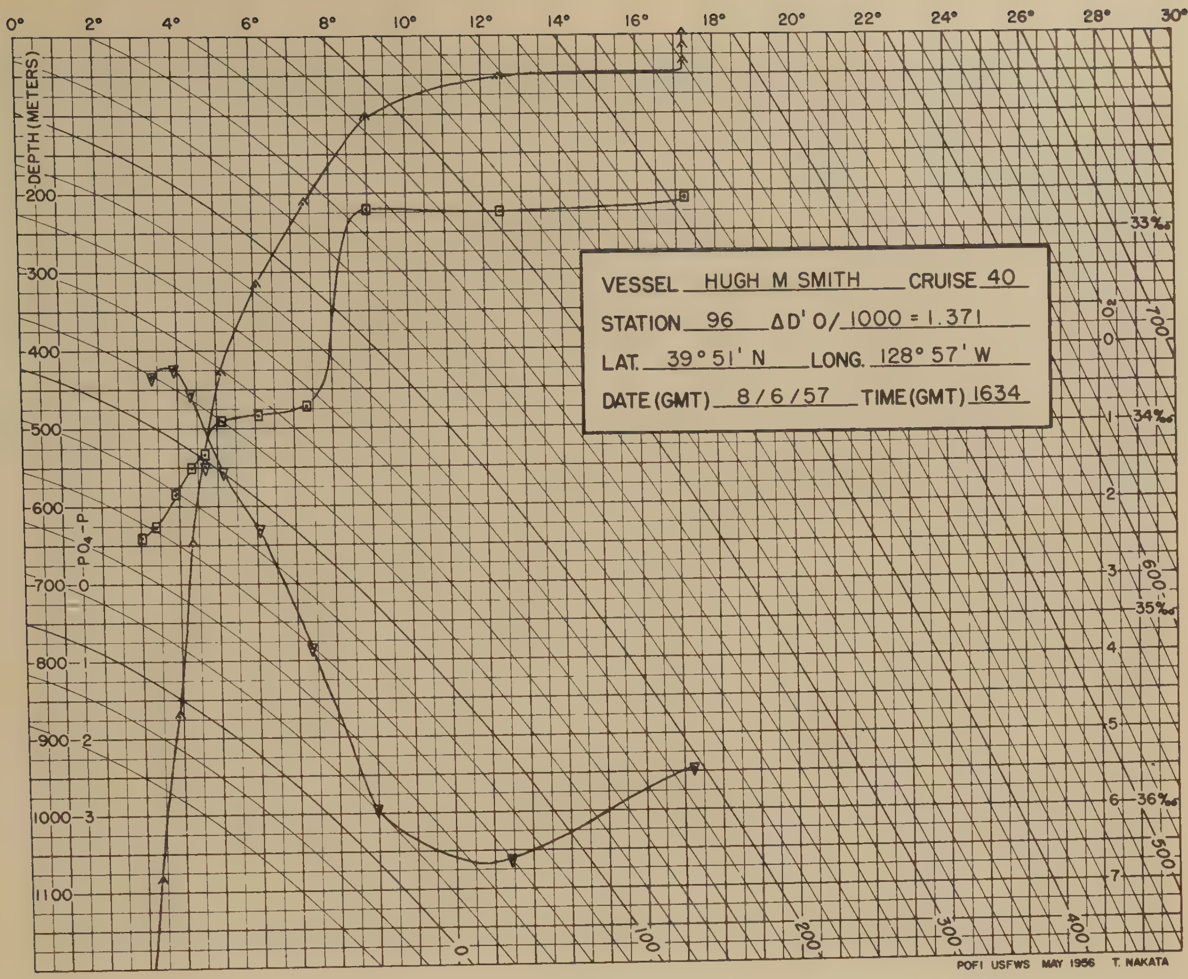
Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	12.18	33.04	291.2	6.21	0.86
10	11.59	33.30	261.9	6.39	0.96
25	11.25	33.48	242.4	6.15	1.22
40	9.84	33.80	195.9	4.95	1.58
99	8.28	33.95	160.9	2.42	2.13
204	7.46	34.11	137.5	1.58	2.35
305	6.63	34.11	126.7	1.47	2.45
412	6.43	34.20	117.4	0.95	2.61
527	5.75	34.23	106.9	0.63	1.68
628	5.16	34.25	98.7	0.43	1.92
844	4.30	34.34	82.9	0.29	2.98
1051	3.72	34.45	69.0	0.34	2.96
1262	3.28	34.56	56.7	0.52	2.72*
1262					2.37*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



Weather: 02, cloud coverage 5. Wind: 300°, 11 kt. Sea: 1-3 ft. Wire angle: 09°.
BT slide: 277. Dry bulb: 60.9°F. Wet bulb: 59.6°F. Barometric pressure: 1017 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O$_2$, ml. /L.	PO$_4$-P, µg at. /L.
0	15.16	33.03	349.9	5.84	0.67
10	15.09	32.99	351.2	5.85	0.68
26	11.54	33.13	273.3	6.08	0.82
52	9.34	33.40	217.6	4.97	1.55
103	7.98	33.62	181.2	3.78	1.78
212	7.18	33.95	145.9	2.54	2.12
318	6.14	34.04	125.7	NS	2.42
430	5.49	34.14	110.8	0.80	1.91
540	5.08	34.18	103.0	0.62	1.42
654	4.57	34.22	94.7	0.43	2.83
876	4.04	34.42	74.3	0.27	2.95
1091	3.48	34.49	63.7	0.43	1.48
1307	3.10	34.60	52.0	0.62	2.12



VESSEL HUGH M SMITH CRUISE 40

STATION 96 ΔD' 0/1000 = 1.371

LAT. 39° 51' N LONG. 128° 57' W

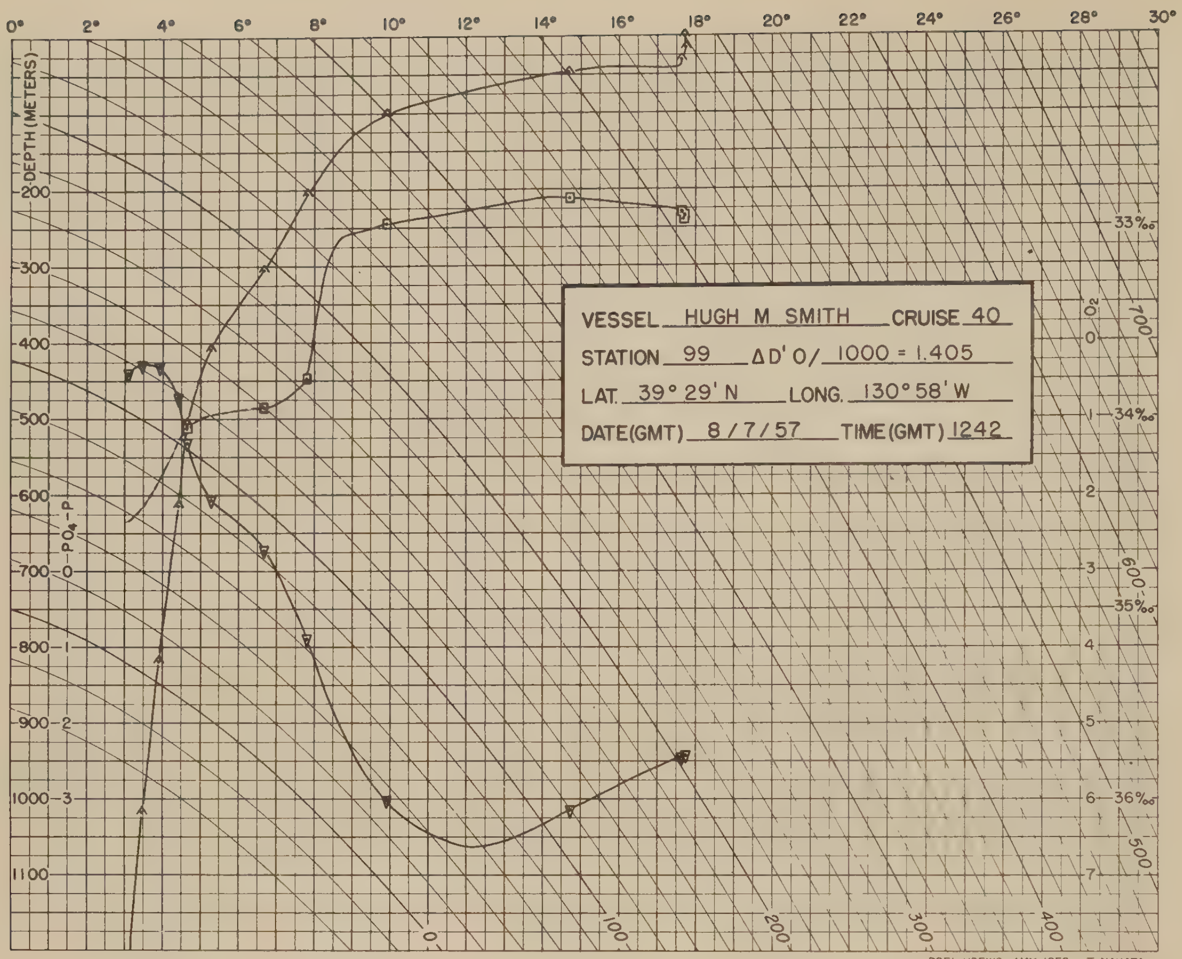
DATE (GMT) 8 / 6 / 57 TIME (GMT) 1634

Weather: 01, cloud coverage 7. Wind: 270°, 06 kt. Sea: 1-3 ft. Wire angle: 10°. BT slide: 285. Dry bulb: 63.8°F. Wet bulb: 62.7°F. Barometric pressure: 1019 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	17.20	32.84	408.0	5.47	0.56
15	17.20	32.83	408.8	5.47	0.54
36	17.20	32.84	408.0	5.47	0.55
53	12.42	32.90	306.0	6.61	0.61
104	8.97	32.88	250.5	5.96	0.98
213	7.34	33.89	152.4	3.85	1.83
318	6.05	33.93	133.0	2.30	2.33
431	5.14	33.96	120.2	1.57	2.60
538	4.67	34.14	101.6	1.50	1.80
650	4.34	34.20	93.8	0.54	1.35
872	3.88	34.34	78.7	0.23	1.79
1086	3.36	34.51	61.2	0.32	1.91
1305	2.99	34.56	53.9	*	2.92 **
1305					2.82 **

* One 02 sample missing; possibly the last.

** Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



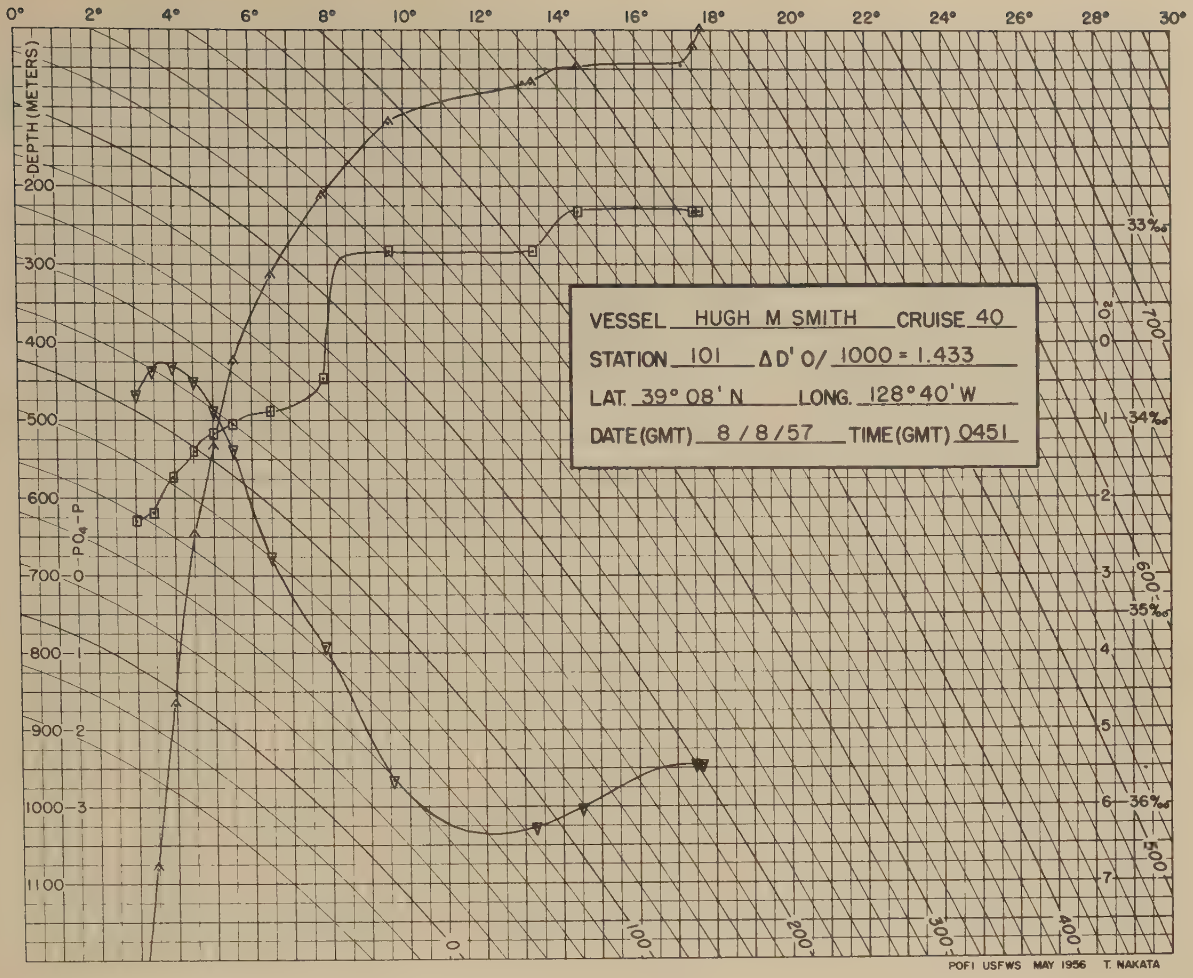
VESSEL HUGH M SMITH CRUISE 40
STATION 99 ΔD' 0/ 1000 = 1.405
LAT. 39° 29' N LONG. 130° 58' W
DATE(GMT) 8/7/57 TIME(GMT) 1242

POFI USFWS MAY 1956 T NAKATA

Weather: 00, cloud coverage not recorded. Wind: 300°, 14 kt. Sea: 3-5 ft. Wire angle: 18°. BT slide: 294. Dry bulb: 62.6°F. Wet bulb: 60.2°F. Barometric pressure: 1019 mb.

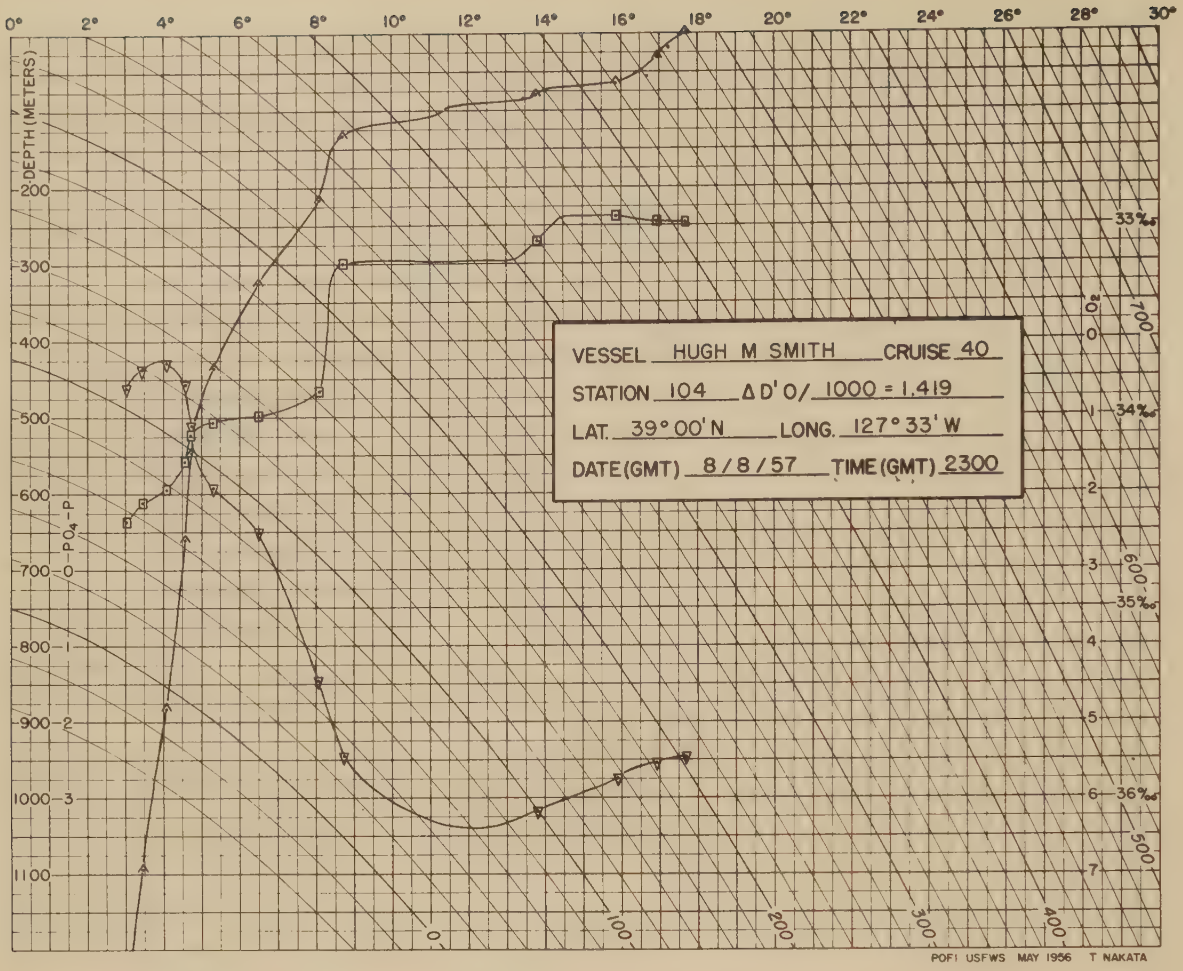
Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	17.72	32.95	411.9	5.42	0.45
15	17.74	32.94	413.0	5.41	0.46
30	17.66	32.92	412.5	5.43	0.50
45	14.70	32.84 Q	354.3	6.14	0.50
100	9.91	32.97	258.1	6.01	0.69
204	7.82	33.78	167.2	3.87	1.64
303	6.68	33.93	140.8	2.72	2.01
408	5.27	NS	-	2.06	2.28
507	4.66	34.04	109.1	1.30	1.81
613	4.42	NS	-	0.70	2.83
817	3.90	NS	-	0.31	2.87
1016	3.45	NS	-	0.28	2.87
1223	3.10	NS	-	0.38	2.75*
1223					2.83*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



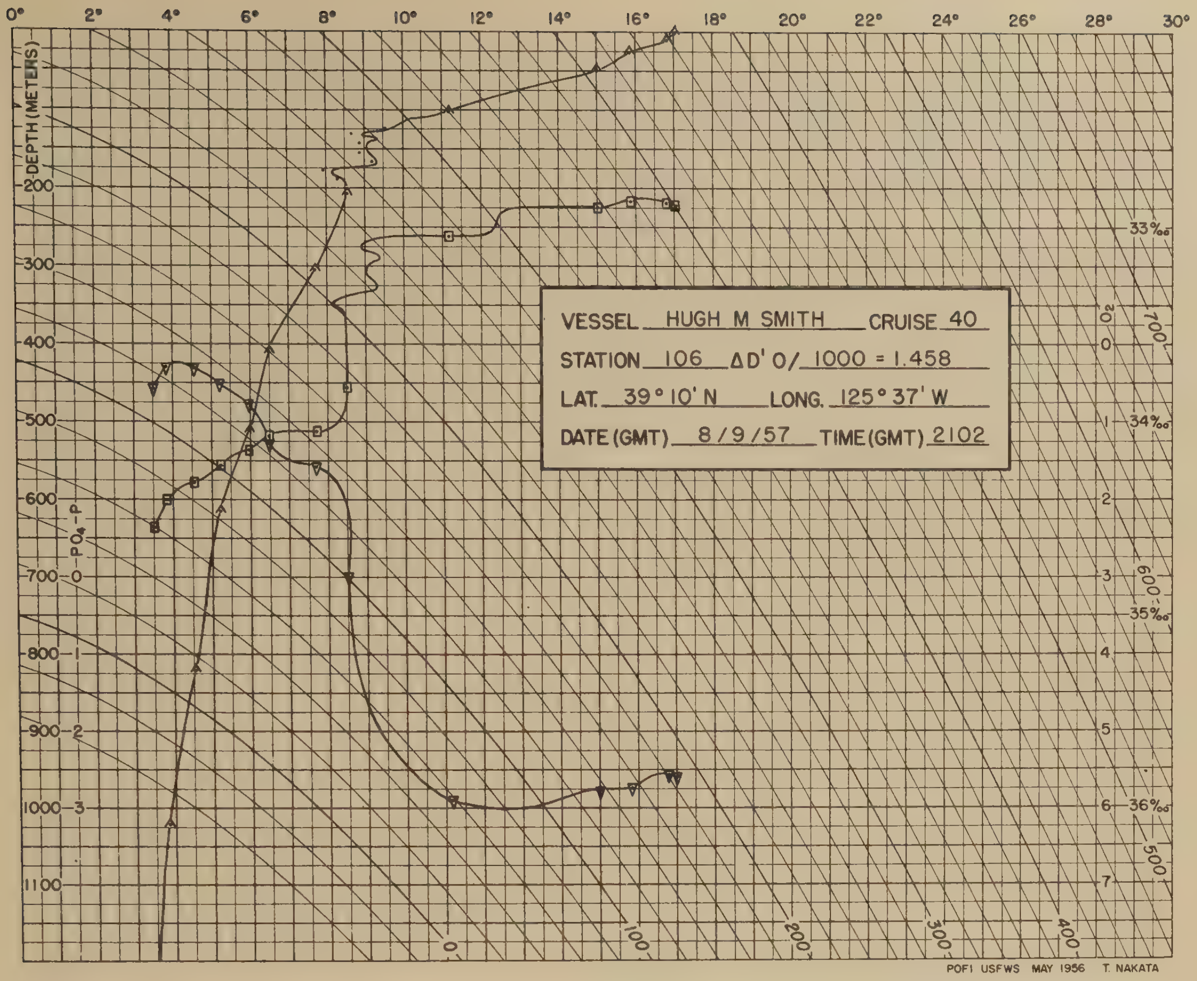
Weather: 02, cloud coverage not recorded. Wind: 310°, 14 kt. Sea: 1-3 ft. Wire angle: 09°. BT slide: 300. Dry bulb: 64.3°F. Wet bulb: 62.5°F. Barometric pressure: 1020 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	17.67	32.92	412.7	5.43	0.57
20	17.50	32.92	409.0	5.43	0.46
46	14.51	32.92	344.7	6.02	0.51
67	13.30	33.13	305.4	6.25	0.51
118	9.60	33.13	241.3	5.65	1.08
212	7.85	33.78	167.5	3.89	1.93
316	6.50	33.95	137.1	2.74	2.40
427	5.53	34.02	120.3	1.35	2.92
534	5.02	34.07	110.6	0.85	2.93
647	4.52	34.16	98.7	0.49	3.47
867	3.93	34.29	83.0	0.31	3.57
1080	3.44	34.47	64.9	0.36	3.44
1297	3.03	34.51	58.1	0.67	3.31



Weather: 01, cloud coverage 6. Wind: 310°, 06 kt. Sea: 1-3 ft. Wire angle: 08°. BT slide: 307. Dry bulb: 67.0°F. Wet bulb: 59.3°F. Barometric pressure: 1021 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O_2, ml. /L.	PO_4-P, μg at. /L.
0	17.67	32.99	407.5	5.47	NS
31	16.94	32.98	391.9	5.54	0.52
63	15.86	32.95	370.2	5.74	0.57
79	13.78	33.08	318.3	6.18	0.60
131	8.73	33.19	224.0	5.46	1.40
216	8.06	33.86	164.6	4.45	1.82
323	6.52	33.99	134.3	2.51	2.64
437	5.31	34.02	117.7	1.92	2.78
547	4.74	34.09	106.2	1.10	3.06
660	4.58	34.23	94.0	0.55	3.55
882	4.06	34.38	77.5	0.29	3.54
1094	3.42	34.45	66.2	0.37	3.60
1305	3.03	34.54	55.9	0.60	3.56



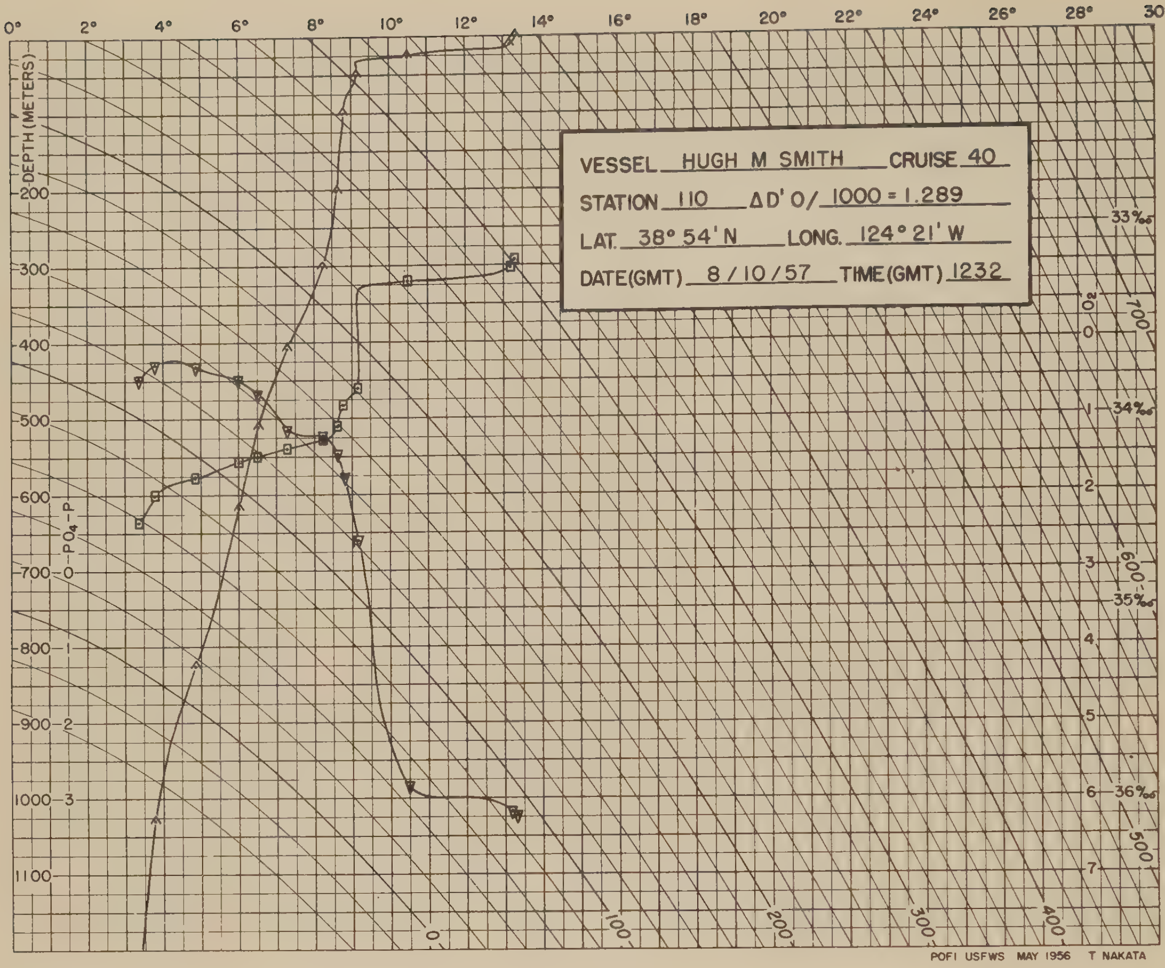
VESSEL HUGH M SMITH CRUISE 40
STATION 106 ΔD' 0/ 1000 = 1.458
LAT. 39° 10' N LONG. 125° 37' W
DATE (GMT) 8/9/57 TIME (GMT) 2102

POFI USFWS MAY 1956 T. NAKATA

Weather: 01, cloud coverage 6. Wind: 340°, 08 kt. Sea: 1-3 ft. Wire angle: 18°.
BT slide: 314. Dry bulb: 64.0°F. Wet bulb: 60.0°F. Barometric pressure: 1019 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	17.02	32.88	400.9	5.58	0.56
10	16.80	32.87	396.2	5.57	0.61
25	15.84	32.86	374.5	5.73	0.51
50	15.02	32.89	357.1	5.74	0.70
100	11.18	33.04	273.7	5.89	1.00
205	8.54	33.82	174.4	2.98	2.23
304	7.68	34.05	145.1	1.55	2.79
409	6.50	34.07	128.0	1.27	2.97
509	5.96	34.14	116.1	0.75	3.04
614	5.22	34.22	101.6	0.51	NG
820	4.56	34.31	87.8	0.31	3.54
1020	3.84	34.40	73.9	0.29	3.54
1226	3.52	34.54	60.5	0.55	3.51*
1226					3.46*

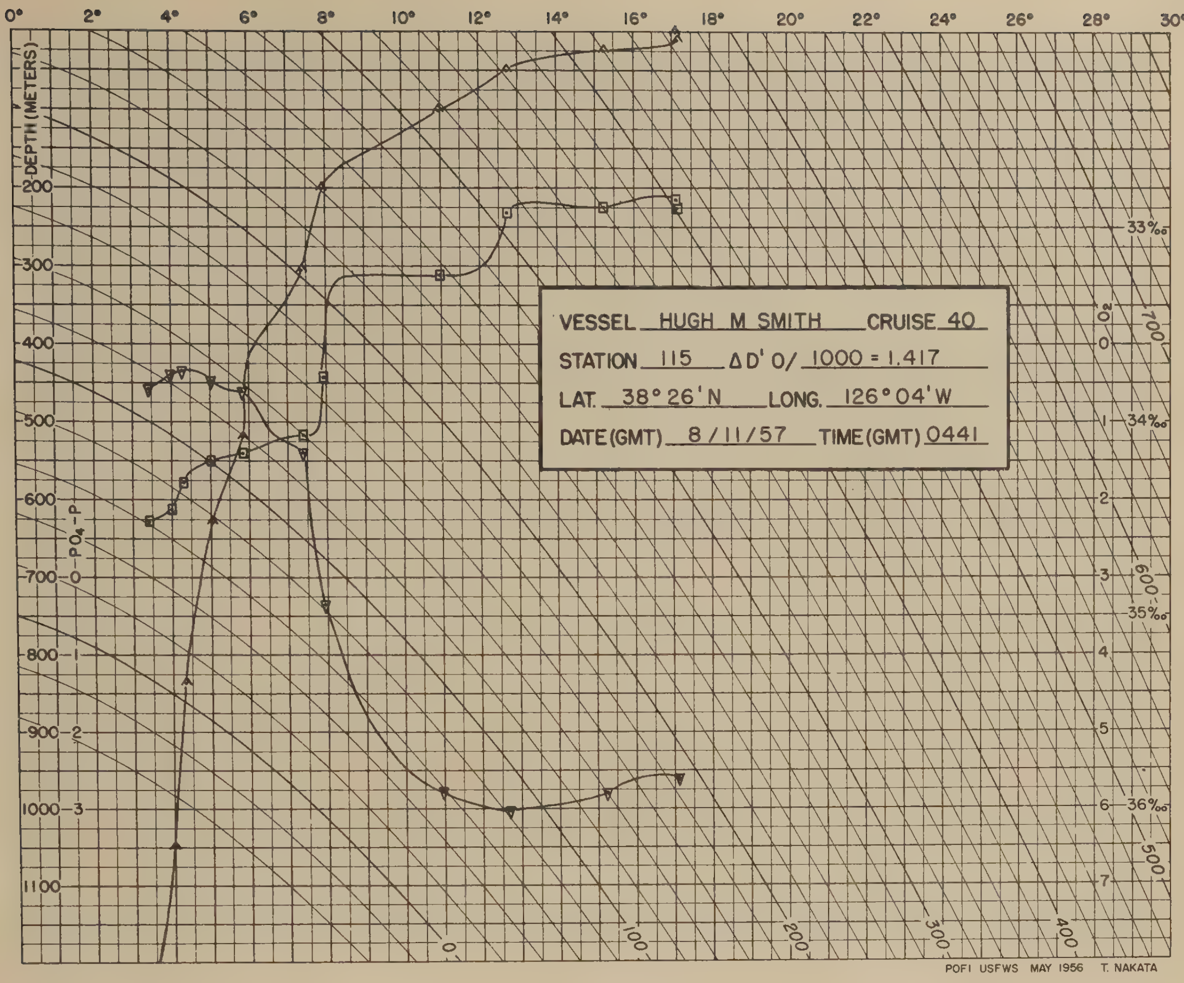
* Values of duplicate did not agree within 0.02 µg at. /L. tolerance so both are carried.



Weather: 02, cloud coverage 1. Wind: 330°, 18 kt. Sea: 3-5 ft. Wire angle: 24°. BT slide: 318. Dry bulb: 58.9°F. Wet bulb: 57.1°F. Barometric pressure: 1015 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O$_2$, ml./L.	PO$_4$-P, µg at./L.
0	13.33	33.17	303.1	6.22	1.17
10	13.18	33.21	297.3	6.18	1.09
24	10.48	33.28	244.2	5.84	1.36
49	9.16	33.84	182.1	2.61	2.65
98	8.80	33.93	170.0	1.78	2.12
202	8.62	34.04	159.3	1.47	2.55
301	8.24	34.11	148.5	1.24	2.74
408	7.30	34.16	131.6	1.16	2.76
510	6.54	34.20	118.9	0.68	2.11
617	6.01	34.23	110.0	0.49	3.53
825	4.87	34.31	90.8	0.31	3.50
1029	3.79	34.40	73.2	0.27	3.66
1237	3.38	34.54	59.0	0.47	3.44*
1237					3.28*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.

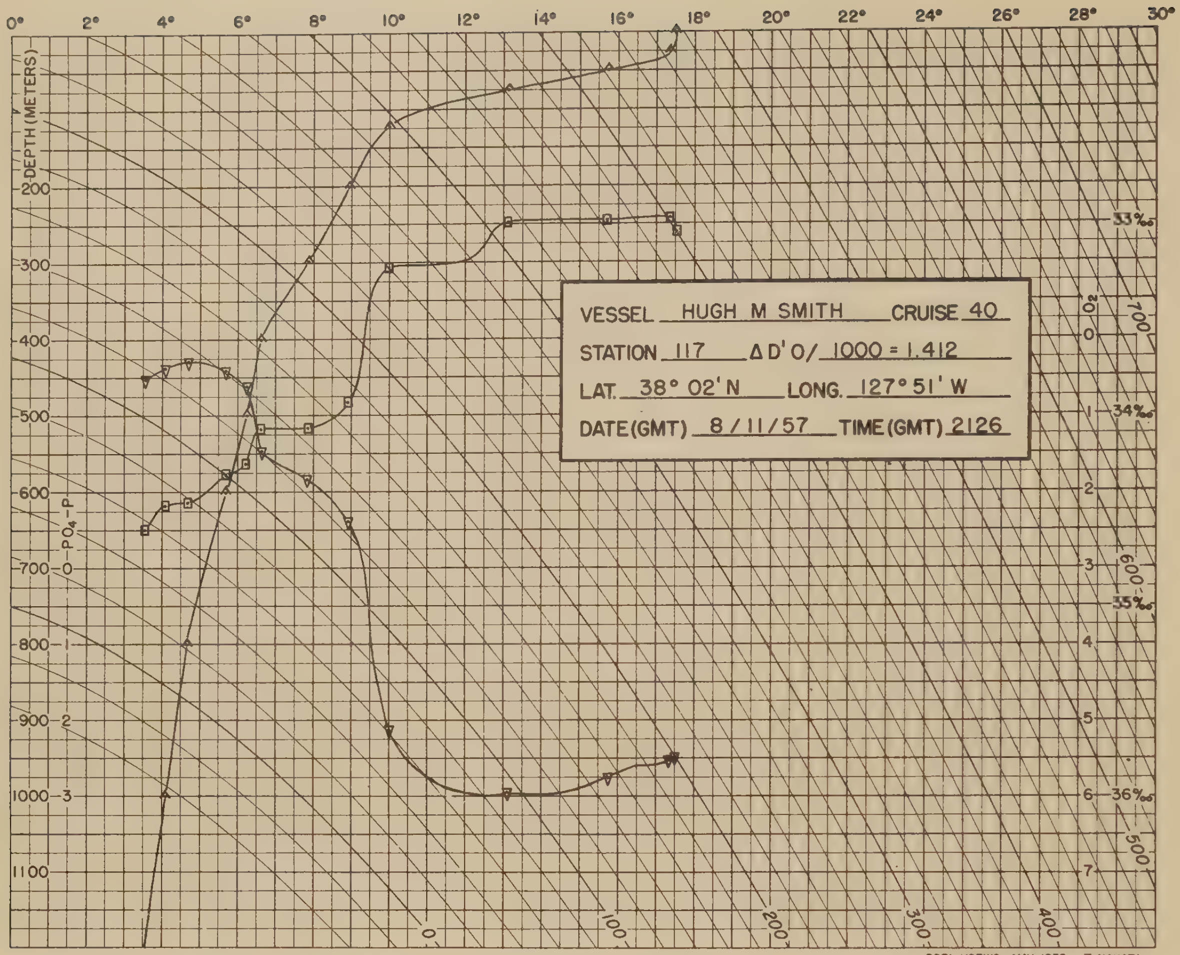


Weather: 02, cloud coverage 2. Wind: 330°, 22 kt. Sea: 3-5 ft. Wire angle: 27°. BT slide: 326. Dry bulb: 62.8°F. Wet bulb: 59.2°F. Barometric pressure: 1018 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	17.10	32.86	404.2	5.60	0.56
9	17.12	32.90	402.0	5.62	0.54
23	15.23	32.89	361.6	5.80	0.74
50	12.72	32.97	306.4	6.03	1.02
100	10.95	33.25	254.2	5.78	1.31
201	7.94	33.77	169.5	3.34	2.27
305	7.40	34.07	139.8	1.40	2.67
PT	-	-	-	-	-
521	5.84	34.16	113.3	0.61	3.12*
628	5.04	34.20	101.0	0.47	3.40
837	4.32	34.31	85.3	0.33	3.56
1049	3.98	34.45	71.3	0.39	3.91
1255	3.42	34.51	61.7	0.58	3.54**
1255					3.39**

* Spilled part of sample.

** Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



VESSEL HUGH M SMITH CRUISE 40

STATION 117 Δ D' 0/ 1000 = 1.412

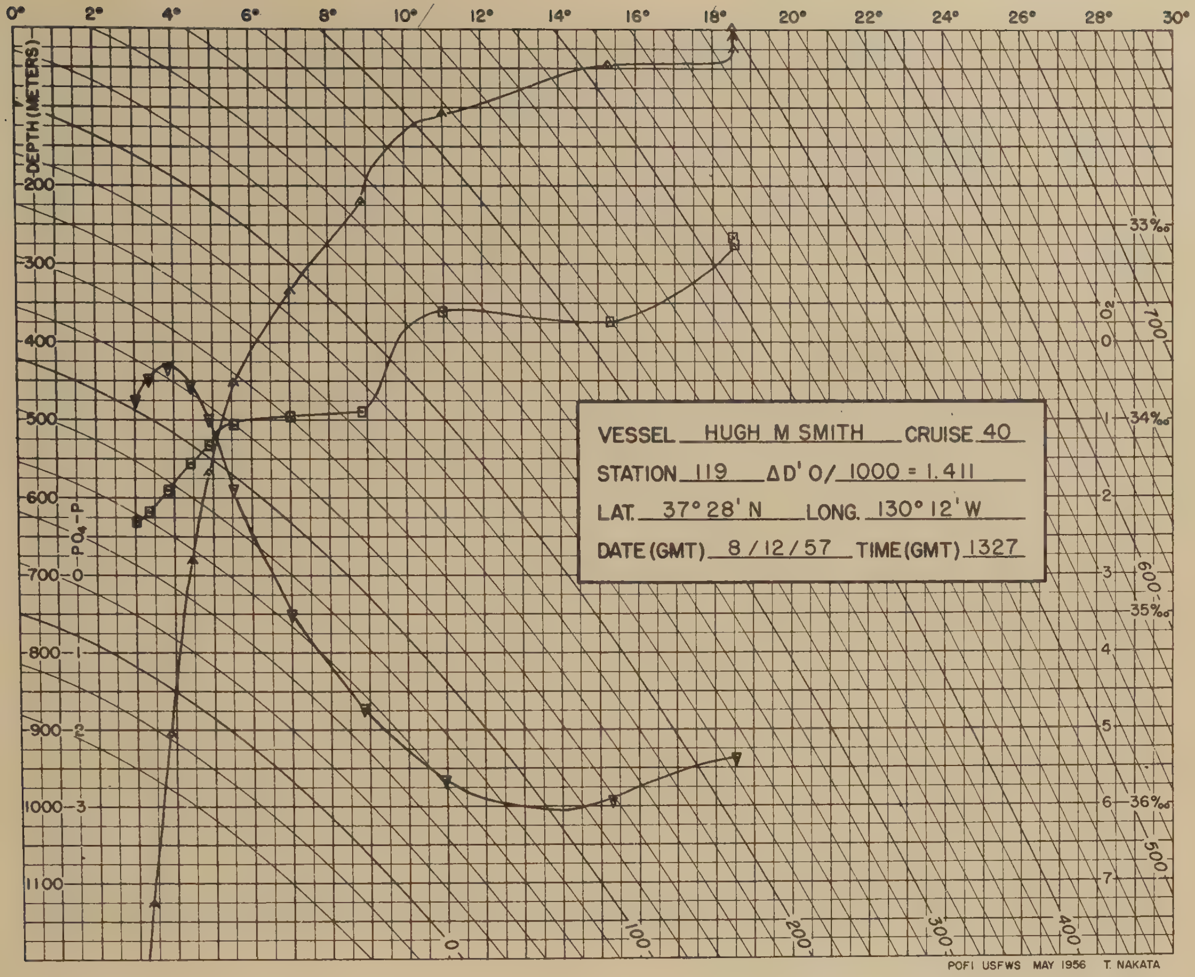
LAT. 38° 02' N LONG. 127° 51' W

DATE (GMT) 8 / 11 / 57 TIME (GMT) 2126

POFI USFWS MAY 1956 T NAKATA

Weather: 01, cloud coverage 2. Wind: 330°, 14 kt. Sea: 1-3 ft. Wire angle: 22°. BT slide: 333. Dry bulb: 64.7°F. Wet bulb: 60.8°F. Barometric pressure: 1021 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, μg at. /L.
0	17.52	33.04	400.7	5.49	0.50
25	17.35	32.97	401.8	5.53	0.50
49	15.74	32.98	365.9	5.74	0.56
73	13.12	32.99	312.3	5.95	0.82
122	10.00	33.25	238.9	5.13	1.40
200	8.94	33.93	172.1	2.39	2.35
297	7.85	34.07	145.9	1.83	2.45
400	6.63	34.07	129.6	1.46	2.68
498	6.27	34.25	111.6	0.61	1.60
601	5.71	34.31	100.6	0.40	2.94
801	4.68	34.45	78.5	0.29	3.14
999	4.08	34.47	70.9	0.35	2.83
1204	3.56	34.60	56.2	0.51	2.42



VESSEL HUGH M SMITH CRUISE 40

STATION 119 ΔD' 0/1000 = 1.411

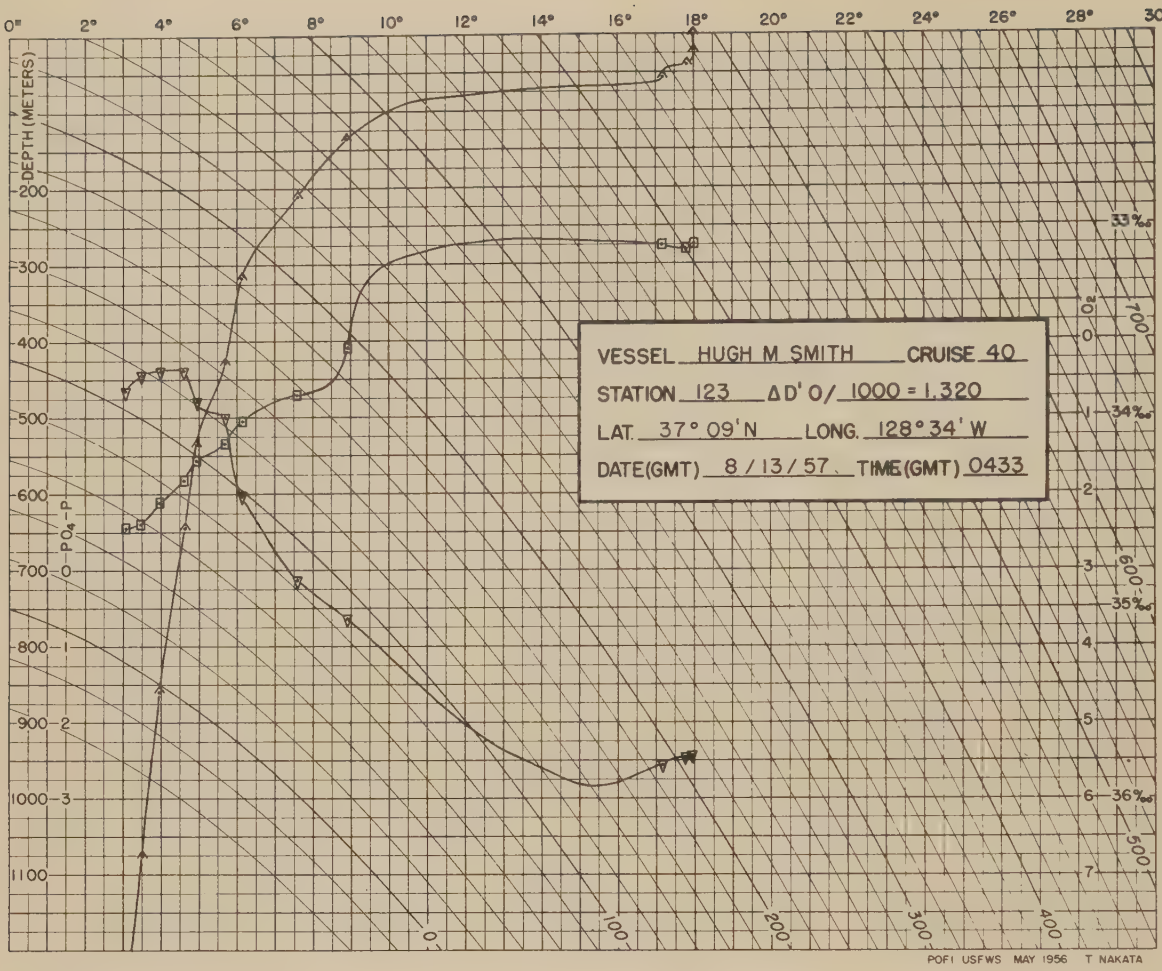
LAT. 37° 28' N LONG. 130° 12' W

DATE (GMT) 8 / 12 / 57 TIME (GMT) 1327

Weather 02, cloud coverage 8. Wind: 320°, 11 kt. Sea: 1-3 ft. Wire angle: 17°. BT slide: 342. Dry bulb: 64.7°F. Wet bulb: 59.2°F. Barometric pressure: 1023 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	18.51	33.06	422.1	5.37	NS
10	18.54	33.10	420.0	5.37	0.41
25	18.55	33.10	420.1	5.36	0.51
45	15.27	33.49	318.7	5.92	0.47
111	10.96	33.44	240.3	5.66	0.62
222	8.86	33.95	169.4	4.72	1.38
335	7.01	33.98	141.4	3.50	1.59
454	5.56	34.02	120.5	1.88	1.87
569	4.90	34.13	104.9	0.99	1.75
683	4.44	34.22	93.3	0.56	1.98
907	3.85	34.36	77.0	0.31	2.72
1129	3.37	34.47	64.3	0.46	2.31
1341	3.02	34.52	57.5	0.73	1.89*
1341					2.09*

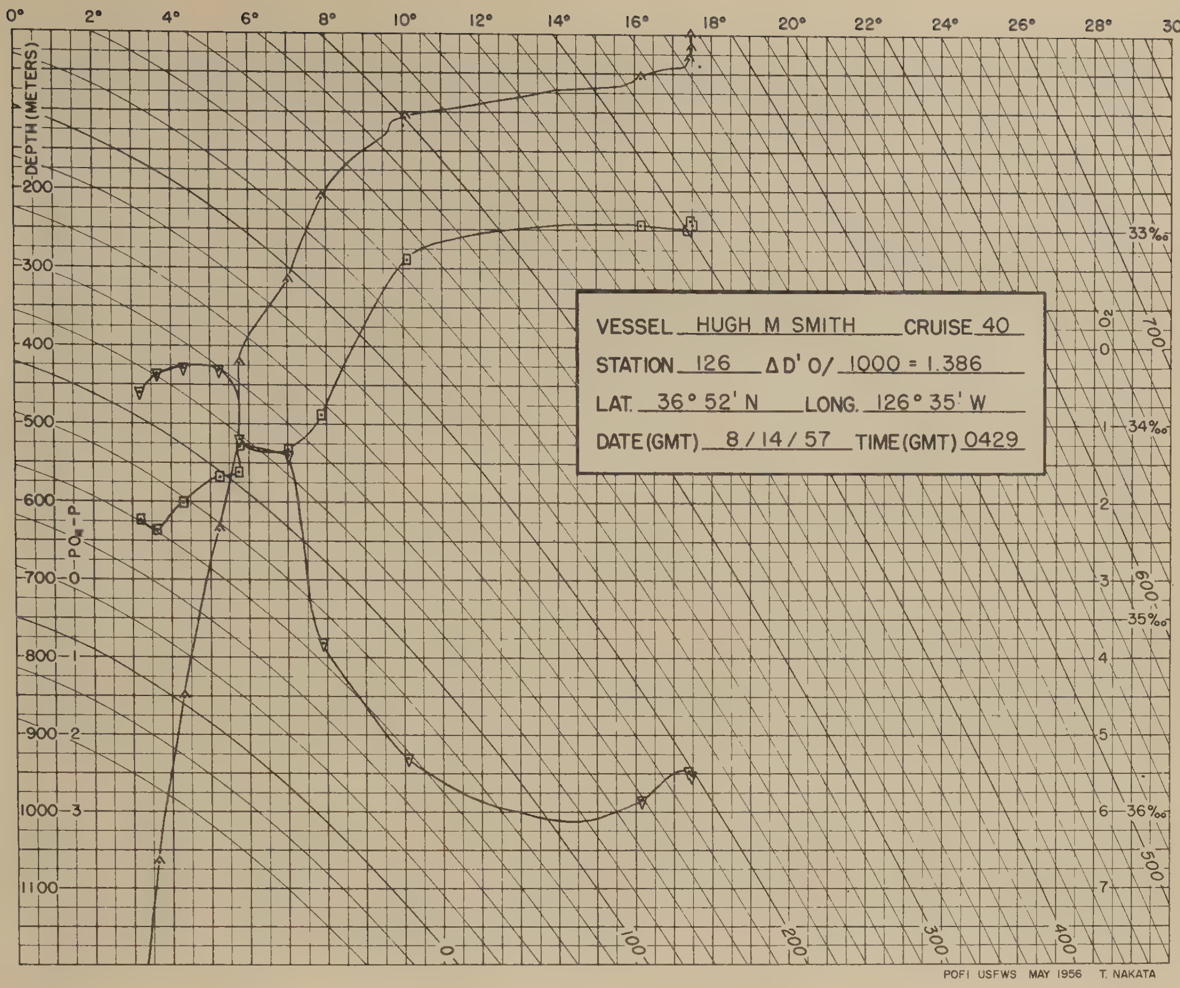
* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.



Weather: 02, cloud coverage 8. Wind: 000°, 15 kt. Sea: 3-5 ft. Wire angle: 22°.
BT slide: 348. Dry bulb: 64.3°F. Wet bulb: 60.0°F. Barometric pressure: 1023 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, μg at. /L.
0	17.94	33.10	406.0	5.45	0.50
19	17.96	33.10	406.3	5.43	0.48
38	17.78	33.12	400.6	5.46	0.50
57	17.15	33.10	387.8	5.56	0.49
134	8.90	33.64	193.0	3.63	1.24
210	7.60	33.89	156.0	3.13	1.58
316	6.14	34.02	127.2	2.01	1.99
428	5.68	34.14	112.9	1.00	2.45
536	4.94	34.22	98.5	0.79	2.10
645	4.62	34.33	87.0	0.37	2.30
859	3.96	34.45	71.1	0.39	2.22
1075	3.46	34.56	58.3	0.44	2.50
1280	3.06	34.58	53.1	0.64	2.08*
1280					1.93*

* Values of duplicate did not agree within 0.02 μg at. /L. tolerance so both are carried.

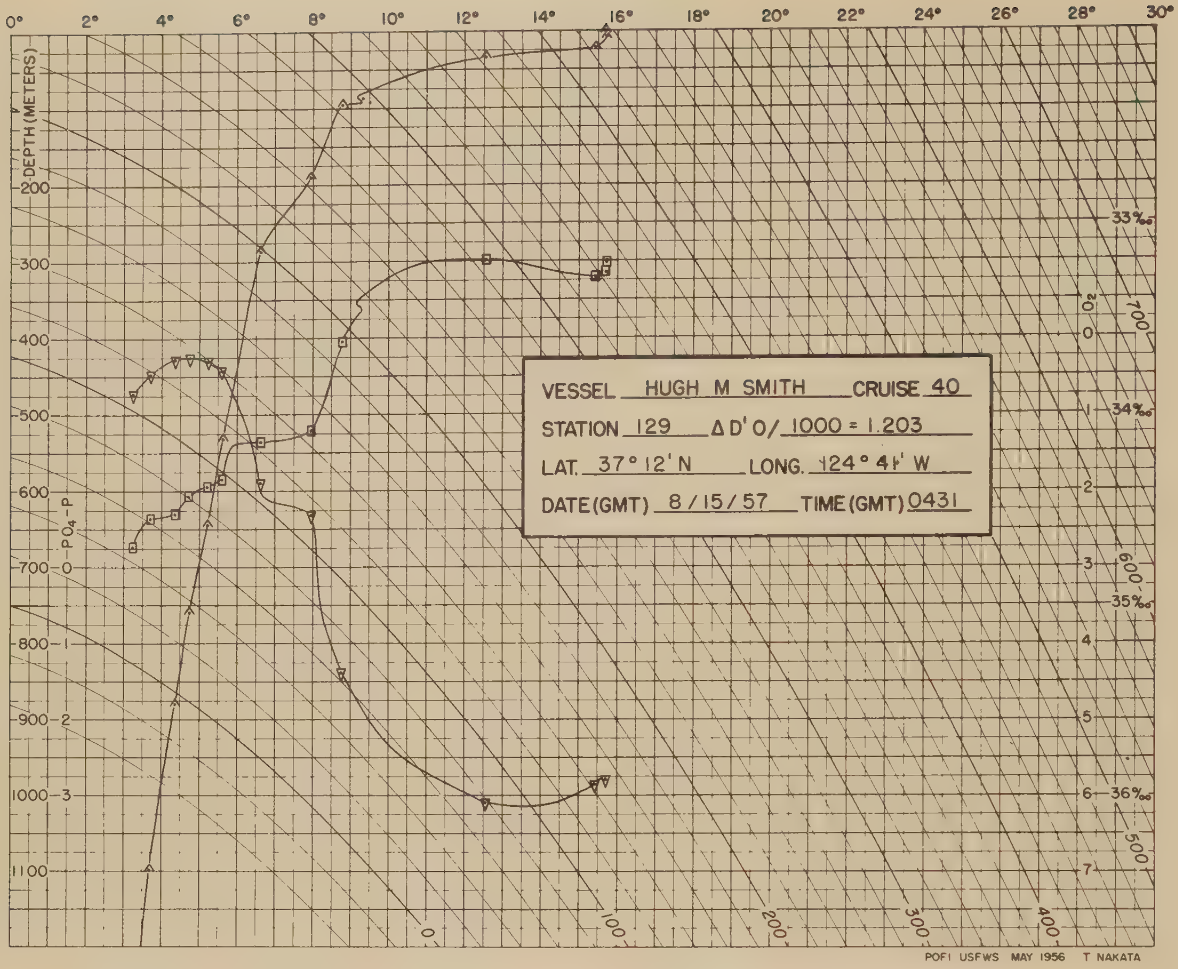


VESSEL HUGH M SMITH CRUISE 40
STATION 126 Δ D' 0/ 1000 = 1.386
LAT. 36° 52' N LONG. 126° 35' W
DATE (GMT) 8 / 14 / 57 TIME (GMT) 0429

POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 2. Wind: 330°, 20 kt. Sea: 3-5 ft. Wire angle: 29°. BT slide: 356. Dry bulb: 63.0°F. Wet bulb: 60.9°F. Barometric pressure: 1020 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	17.44	32.95	405.2	5.50	0.57
15	17.46	32.97	404.1	5.50	0.51
29	17.40	32.99	401.2	5.48	0.54
53	16.16	32.97	375.4	5.84	0.55
105	10.08	33.15	247.6	5.30	1.23
209	7.88	33.95	155.2	3.80	1.94
314	7.01	34.13	129.9	1.40	2.10
422	5.77 Q	34.11	116.2	1.22	3.04
528	5.73	34.25	105.2	0.54	1.78
636	5.22	34.27	97.9	0.30	3.04
850	4.32	34.40	78.6	0.27	3.39
1065	3.62	34.54	61.2	0.36	2.82
1272	3.18	34.49	61.0	0.60	2.87

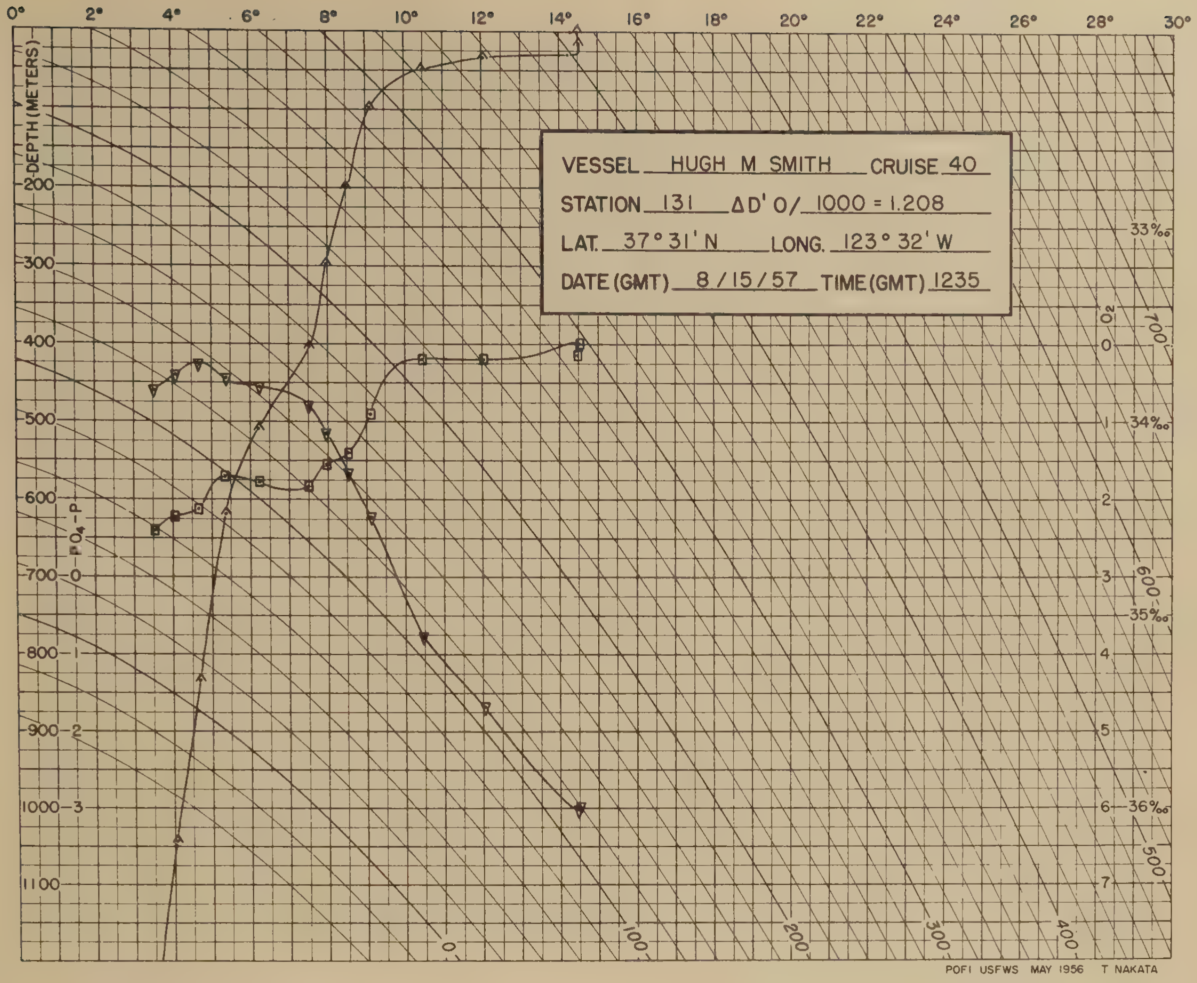


VESSEL HUGH M SMITH CRUISE 40
STATION 129 Δ D' 0/ 1000 = 1.203
LAT. 37° 12' N LONG. 124° 41' W
DATE (GMT) 8/15/57 TIME (GMT) 0431

Weather: 02, cloud coverage 1. Wind: 320°, 17 kt. Sea: 3-5 ft. Wire angle: 28°, 28°. BT slide: 365. Dry bulb: 61.1°F. Wet bulb: 59.2°F. Barometric pressure: 1017 mb.

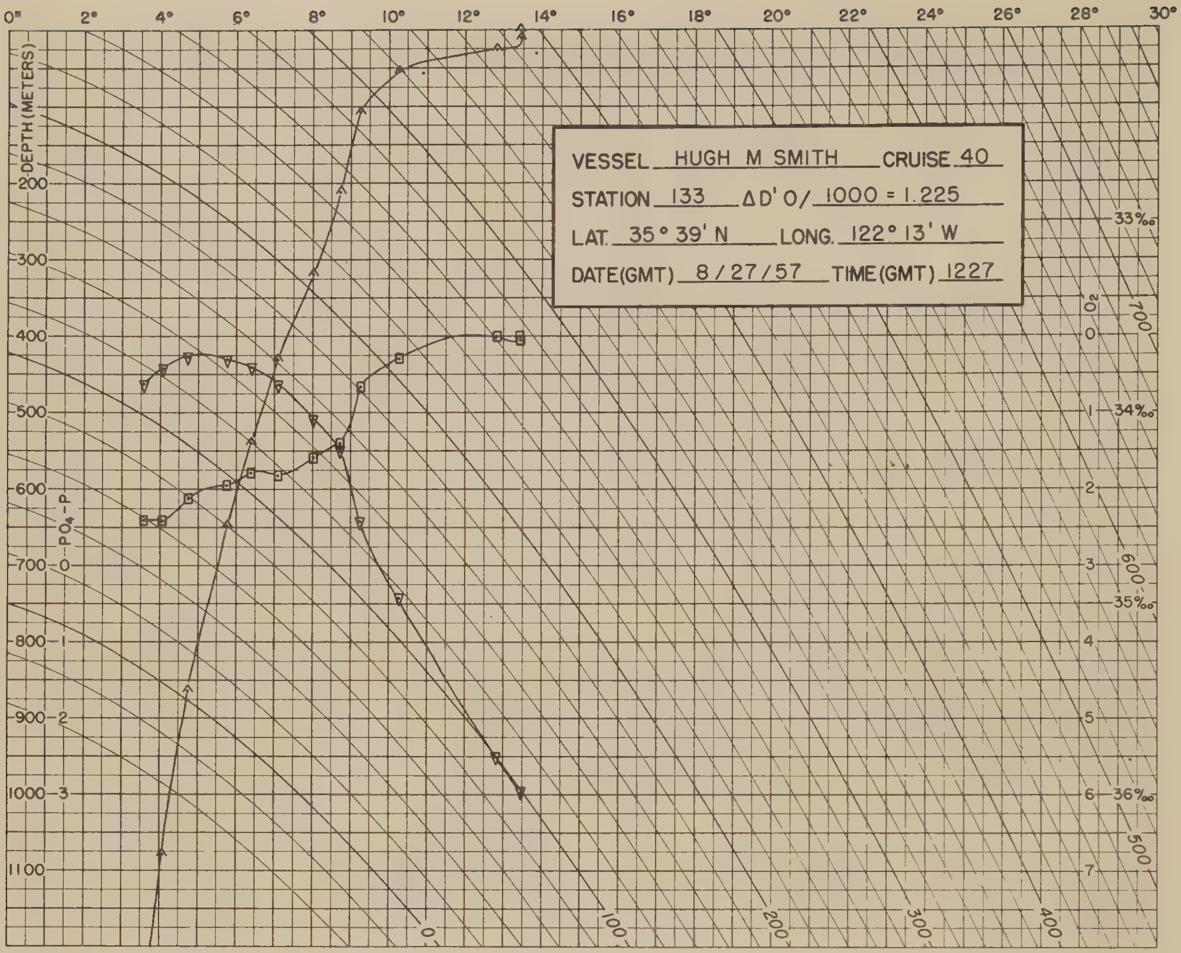
	Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
	0	15.68	33.21	347.8	5.80	0.57
	8	15.70	33.26	344.6	5.79	0.84
	21	15.42	33.28	337.0	5.85	0.64
	34	12.56	33.19	287.1	6.10	0.73
	95	8.78	33.62	192.8	4.38	1.09
	190	7.94	34.09	145.6	2.32	2.08
I	287	6.64	34.14	124.5	1.88	2.11
II	534	5.61	34.34	97.2	0.43	3.06
	645	5.22	34.38	89.7	0.31	2.80
	759	4.74	34.43	80.6	0.26	2.95
	879	4.36	34.52	70.0	0.28	2.80
	1099	3.70	34.54	62.0	0.48	2.97
	1308	3.24	34.69	46.5	0.73	2.66*
	1308					2.83*

* Values of duplicate did not agree within 0.02 µg at./L. tolerance so both are carried.


VESSEL HUGH M SMITH CRUISE 40
STATION 131 ΔD' 0/1000 = 1.208
LAT. 37° 31' N LONG. 123° 32' W
DATE (GMT) 8/15/57 TIME (GMT) 1235

Weather: 00, cloud coverage not recorded. Wind: 320°, 23 kt. Sea: 5-8 ft. Wire angle: 27°. BT slide: 369. Dry bulb: 58.3°F. Wet bulb: 56.4°F. Barometric pressure: 1016 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	14.46	33.66	289.4	6.02	0.63
14	14.52	33.60	295.0	6.00	0.63
33	12.04	33.68	241.8	4.68	1.50
48	10.44	33.68	214.1	3.77	1.76
96	9.11	33.96	172.7	2.24	1.27
198	8.54	34.16	149.2	1.67	2.22
297	7.96	34.22	136.1	1.14	2.27
403	7.52	34.33	122.0	0.79	2.09
508	6.24	34.34	106.8	0.54	2.83
618	5.36	34.29	98.0	0.44	2.34
834	4.66	34.45	78.3	0.26	1.57
1043	4.04	34.49	69.0	0.40	3.03
1255	3.52	34.56	58.9	0.59	2.43

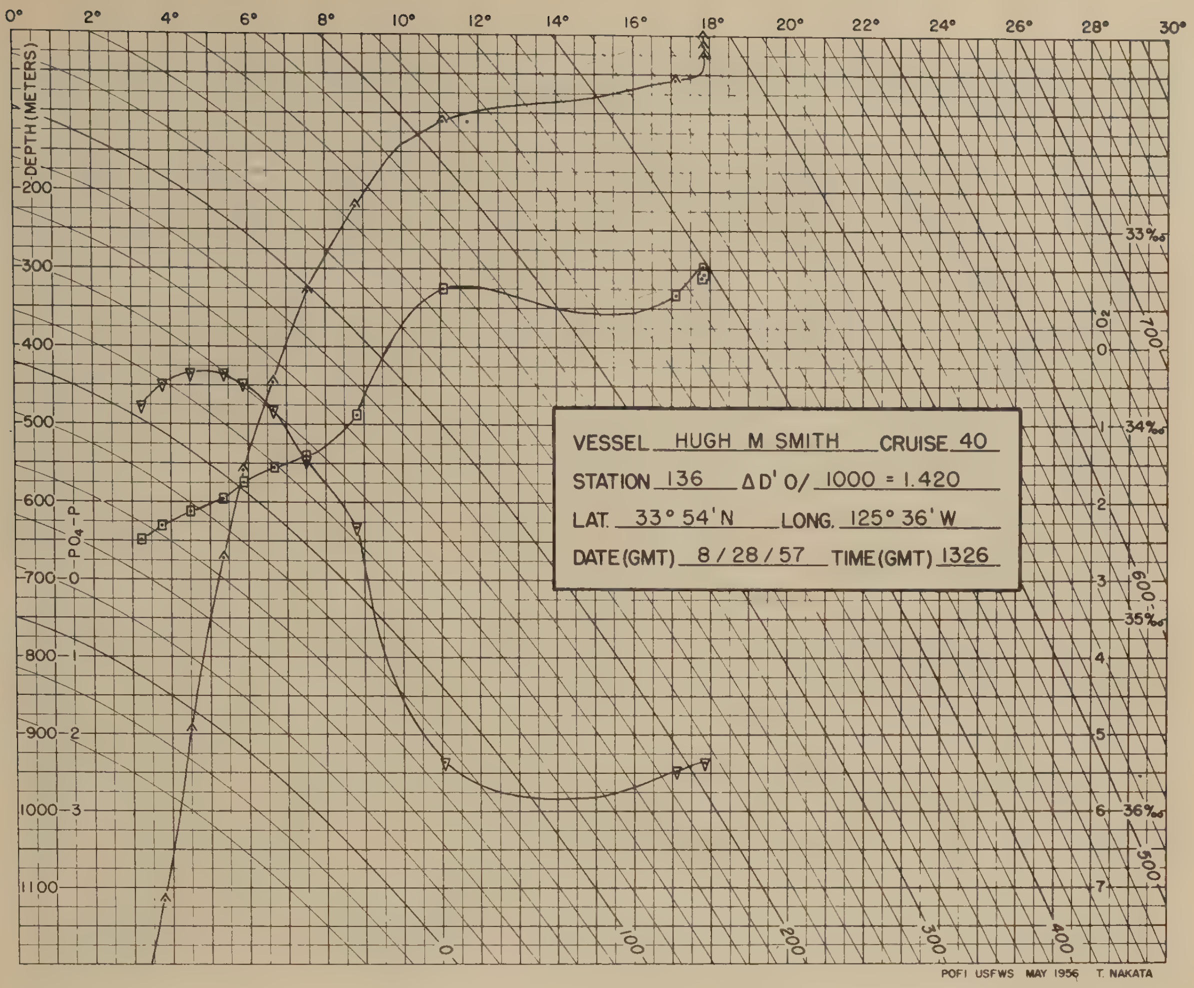


VESSEL HUGH M SMITH CRUISE 40
STATION 133 ΔD' 0/1000 = 1.225
LAT. 35° 39' N LONG. 122° 13' W
DATE (GMT) 8/27/57 TIME (GMT) 1227

POFI USFWS MAY 1956 T NAKATA

Weather: 00, cloud coverage 2. Wind: 320°, 18 kt. Sea: 3-5 ft. Wire angle: 26°. BT slide: 374. Dry bulb: 59.8°F. Wet bulb: 57.0°F. Barometric pressure: 1020 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O_2, ml./L.	PO_4-P, μg at./L.
0	13.44	33.60	273.7	5.96	1.12
10	13.44	33.62	272.1	5.96	0.88
24	12.84	33.60	262.3	5.50	1.08
53	10.26	33.71	209.0	3.42	1.86
106	9.25	33.86	182.0	2.42	1.29
212	8.74	34.16	152.1	1.49	2.60
319	8.00	34.23	136.0	1.07	3.07
431	7.10	34.33	116.2	0.62	3.40
539	6.41	34.31	109.0	0.40	2.66
648	5.76	34.38	95.8	0.30	3.17
863	4.74	34.45	79.1	0.27	3.47
1078	4.06	34.56	63.9	0.42	3.43
1283	3.56	34.56	59.1	0.61	2.36



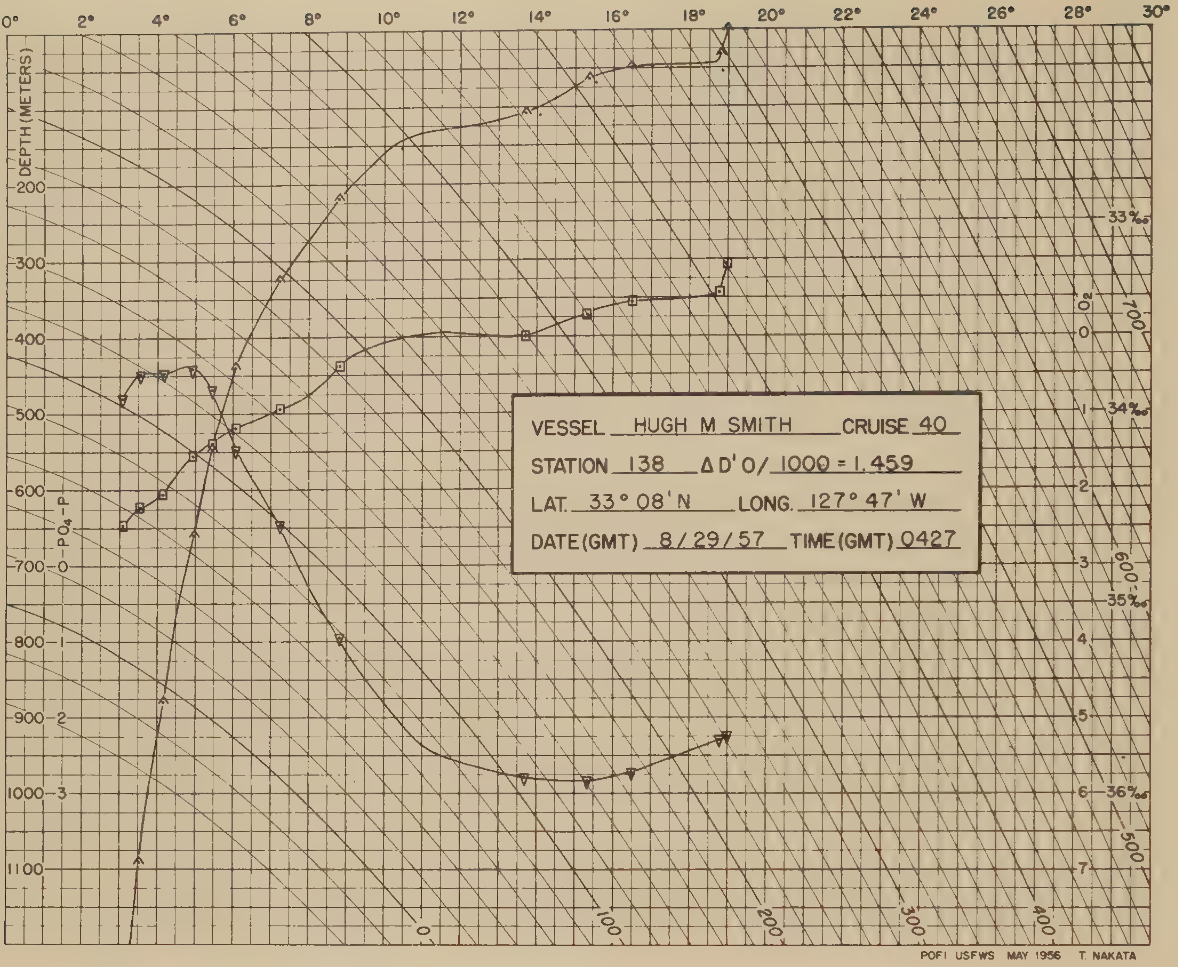
VESSEL HUGH M SMITH CRUISE 40
STATION 136 ΔD' 0/1000 = 1.420
LAT. 33° 54' N LONG. 125° 36' W
DATE (GMT) 8 / 28 / 57 TIME (GMT) 1326

POFI USFWS MAY 1956 T. NAKATA

Weather: 00, cloud coverage 3. Wind: 320°, 20 kt. Sea: 3-5 ft. Wire angle: 20°. BT slide: 386. Dry bulb: 63.0°F. Wet bulb: 58.0°F. Barometric pressure: 1021 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O_2, ml./L.	PO_4-P, μg at./L.
0	17.82	33.24	392.9	5.35	0.58
10	17.84	33.22	395.0	5.35	0.54
25	17.84	33.19	397.1	5.37	0.51
55	17.12	33.33	370.3	5.49	0.54
110	11.06	33.30	252.5	5.36	0.76
218	8.80	33.95	168.6	2.31	2.02
328	7.53	34.16	134.7	1.46	2.72
445	6.67	34.22	118.8	0.81	2.85
558	5.87	34.29	103.8	0.48	3.46
671	5.36	34.38	91.3	0.35	3.12
894	4.52	34.45	76.8	0.33	3.39
1117	3.78	34.52	64.2	0.48	3.40
1328	3.25	34.58	55.0	0.76	2.42*
1328					2.17*

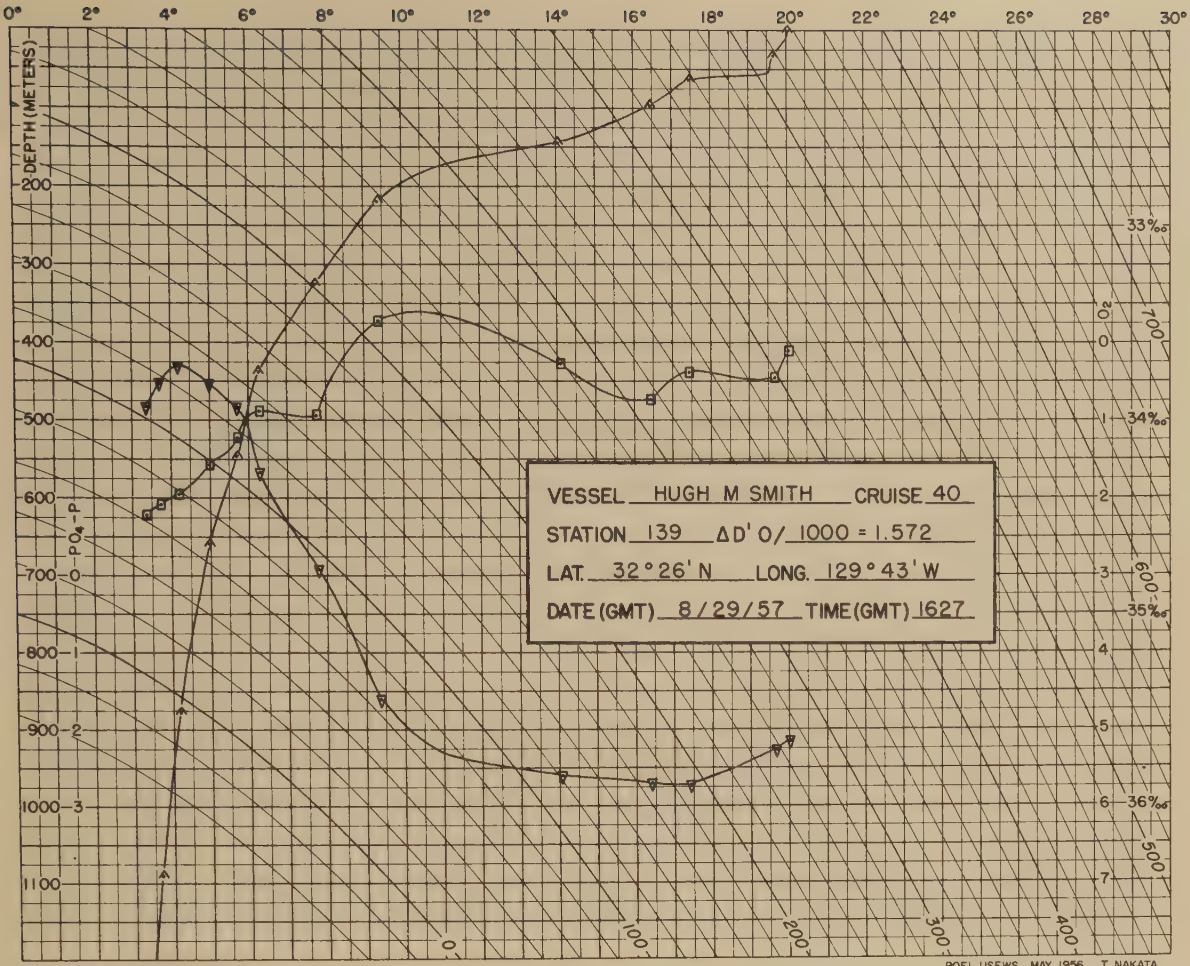
* Values of duplicate did not agree within 0.02 μg at./L. tolerance so both are carried.



Weather: 02, cloud coverage 4. Wind: 330°, 08 kt. Sea: 1-3 ft. Wire angle: 06°. BT slide: 392. Dry bulb: 66.1°F. Wet bulb: 61.3°F. Barometric pressure: 1020 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O_2, ml. /L.	PO_4-P, µg at. /L.
0	18.98	33.22	421.7	5.25	0.47
32	18.79	33.37	406.1	5.28	0.47
48	16.48	33.42	349.6	5.72	0.49
64	15.34	33.49	320.0	5.84	0.47
107	13.71	33.60	278.9	5.78	0.51
219	8.82	33.75	183.8	3.94	1.88
326	7.24	33.98	144.5	2.45	2.34
439	6.07	34.07	122.6	1.47	3.09
547	5.45	34.16	108.8	0.68	3.35
659	4.94	34.22	98.5	0.39	2.90
878	4.16	34.42	75.4	0.46	3.26
1092	3.54	34.49	64.3	0.47	2.99
1307	3.08	34.58	53.3	0.79	3.01*
1307					3.12*

* Values of duplicate did not agree within 0.02 µg at. /L. tolerance so both are carried.

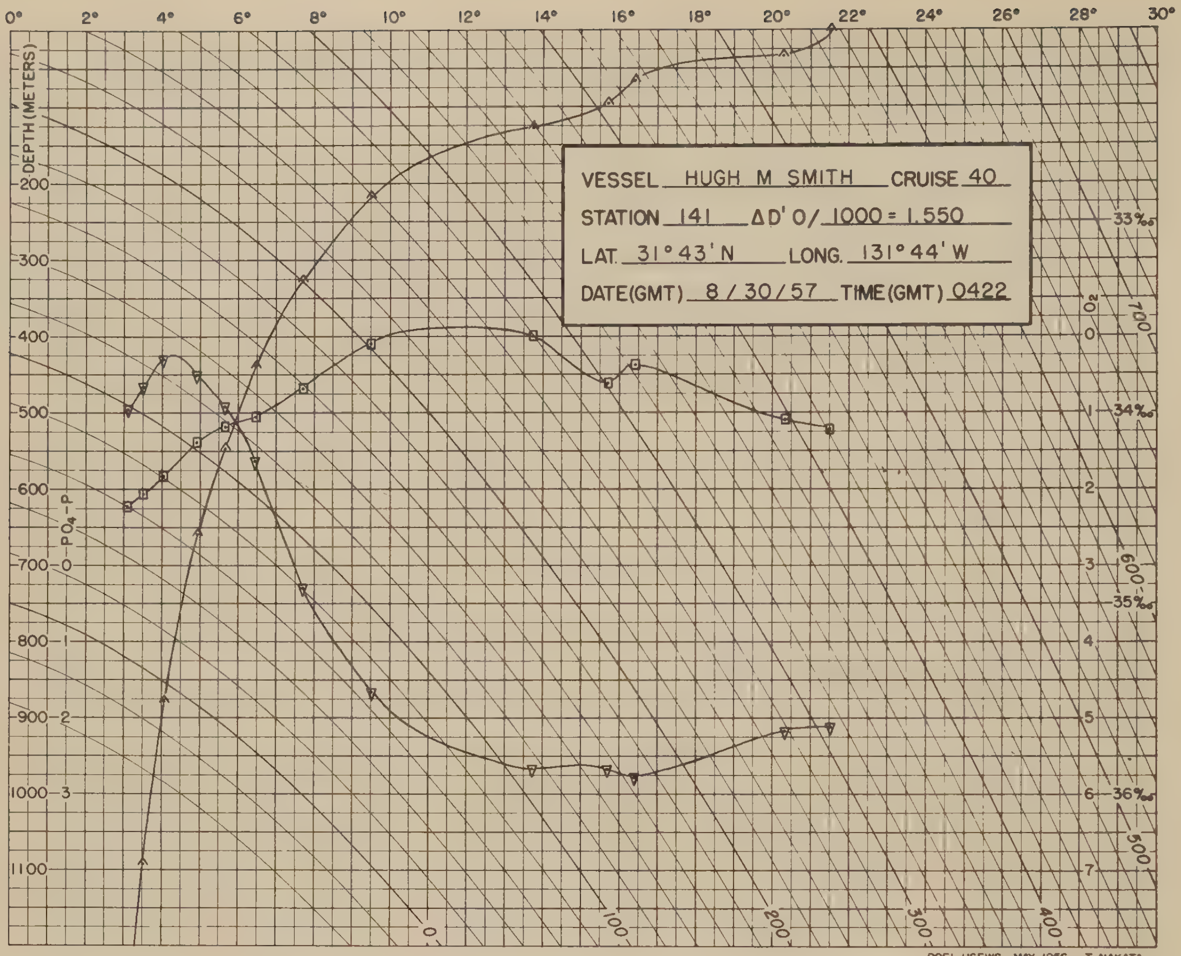


VESSEL HUGH M SMITH CRUISE 40
STATION 139 ΔD' 0/1000 = 1.572
LAT. 32°26' N LONG. 129°43' W
DATE (GMT) 8/29/57 TIME (GMT) 1627

POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 1. Wind: 340°, 05 kt. Sea: < 1 ft. Wire angle: 04°. BT slide: 395. Dry bulb: 67.8°F. Wet bulb: 62.1°F. Barometric pressure: 1020 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	20.02	33.64	416.6	5.16	-
32	19.67	33.78	397.7	5.25	-
64	17.43	33.75	346.8	5.72	-
96	16.43	33.89	314.1	5.71	-
143	14.08	33.71	278.1	5.59	-
218	9.39	33.49	211.6	4.60	-
325	7.77	33.98	151.6	2.92	-
438	6.30	33.95	134.7	1.66	-
546	5.73	34.09	117.3	0.84	-
659	5.00	34.23	98.3	0.54	-
878	4.20	34.38	78.8	0.31	-
1091	3.70	34.43	70.2	0.53	-
1307	3.36	34.49	62.7	0.82	-

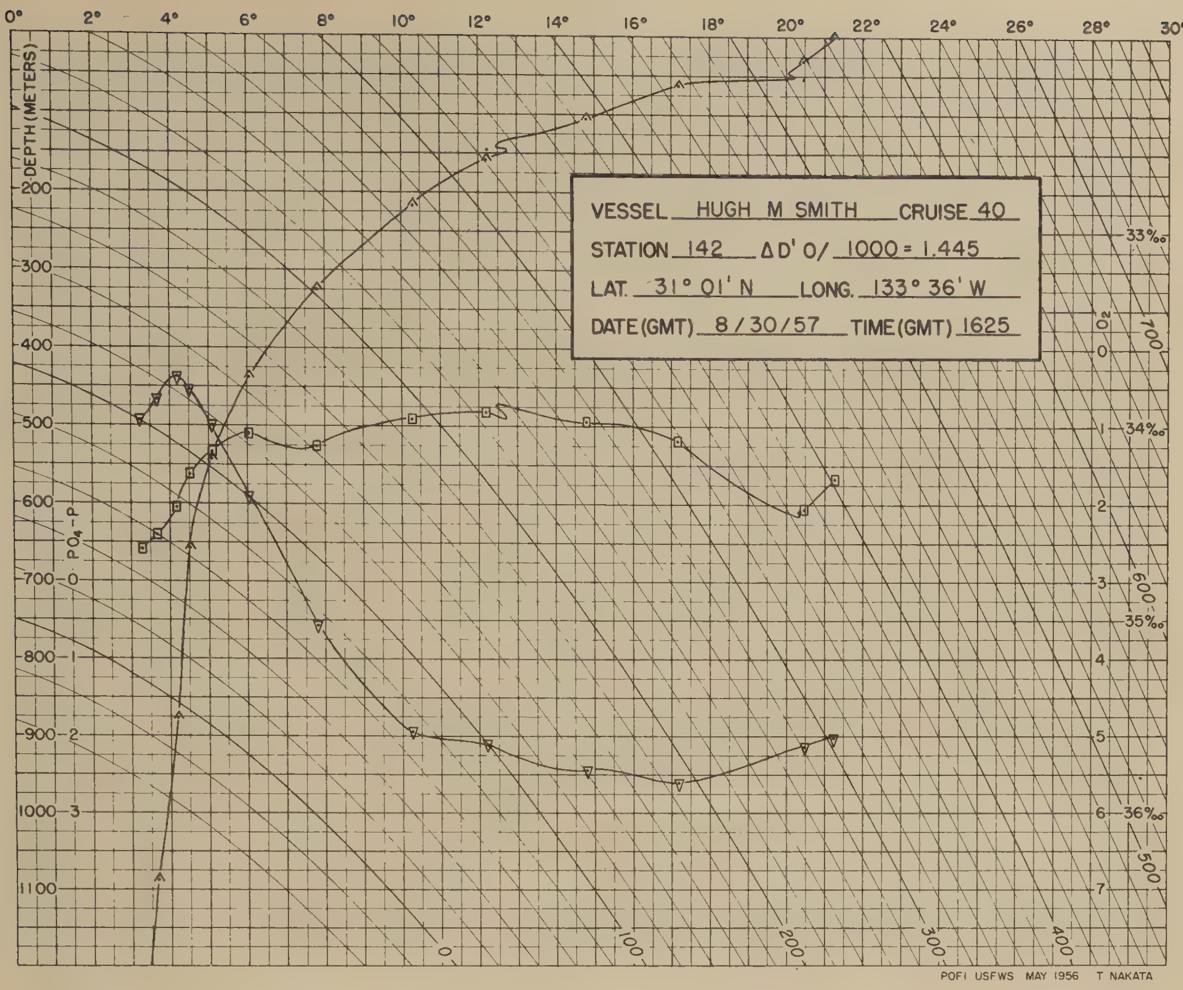


VESSEL HUGH M SMITH CRUISE 40
STATION 141 ΔD' 0/1000 = 1.550
LAT. 31° 43' N LONG. 131° 44' W
DATE (GMT) 8 / 30 / 57 TIME (GMT) 0422

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 3. Wind: 270°, 04 kt. Sea: < 1 ft. Wire angle: 03°. BT slide: 400. Dry bulb: 70.5°F. Wet bulb: 64.0°F. Barometric pressure: 1020 mb.

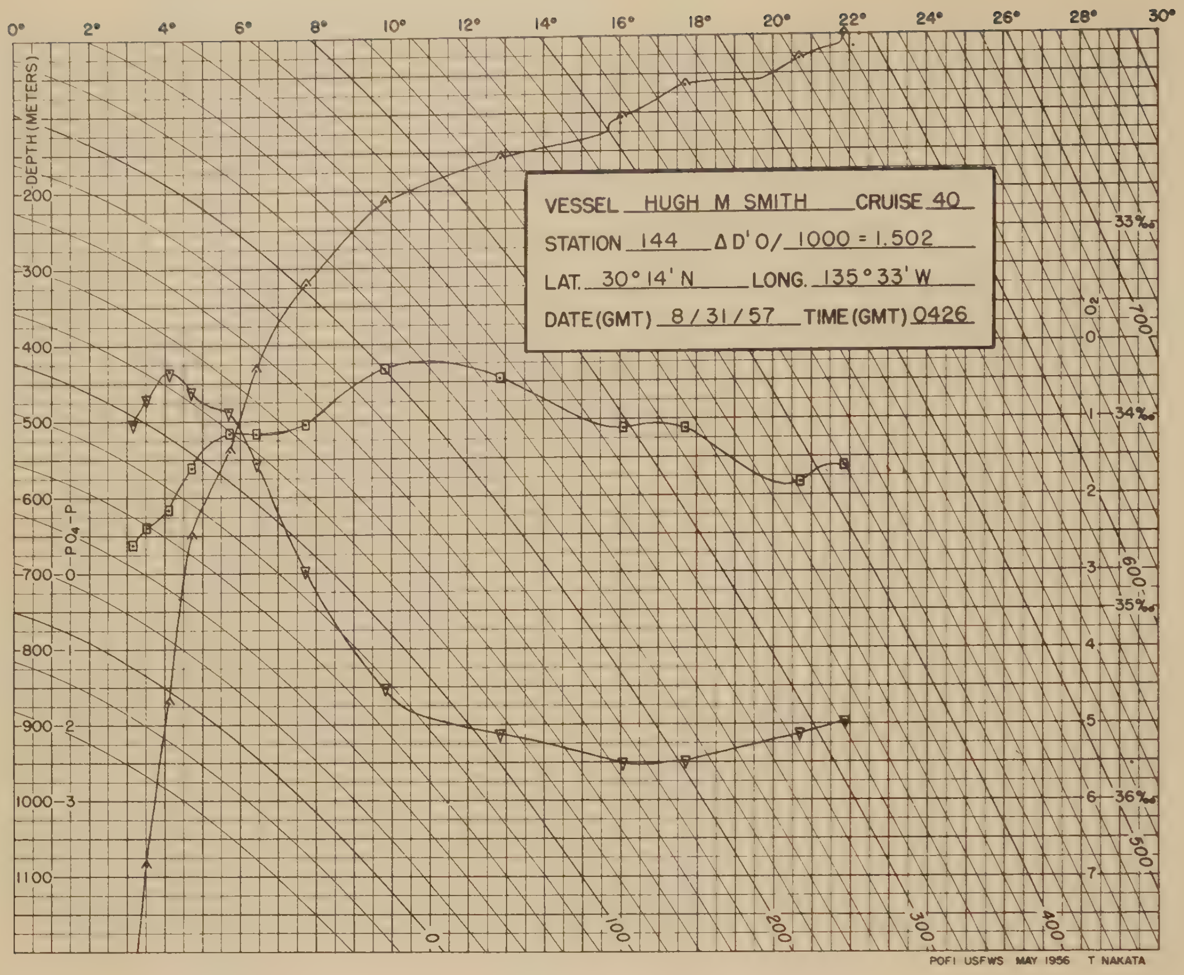
Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	21.54	34.09	423.2	5.13	-
32	20.32	34.04	395.2	5.17	-
64	16.41	33.75	324.0	5.78	-
95	15.71	33.84	302.5	5.67	-
127	13.74	33.60	279.5	5.65	-
217	9.52	33.64	202.4	4.65	-
325	7.72	33.87	159.0	3.29	-
438	6.48	34.02	131.5	1.62	-
546	5.66	34.07	117.8	0.92	-
659	4.94	34.16	103.0	0.50	-
879	4.06	34.33	81.2	0.29	-
1092	3.52	34.43	68.6	0.67	-
1306	3.11	34.49	60.4	0.95	-



VESSEL HUGH M SMITH CRUISE 40
STATION 142 ΔD' 0/ 1000 = 1.445
LAT. 31° 01' N LONG. 133° 36' W
DATE (GMT) 8/30/57 TIME (GMT) 1625

Weather: 03, cloud coverage 4. Wind: 270°, 08 kt. Sea: < 1 ft. Wire angle: 05°.
BT slide: 404. Dry bulb: 72.0°F. Wet bulb: 67.6°F. Barometric pressure: 1021 mb.

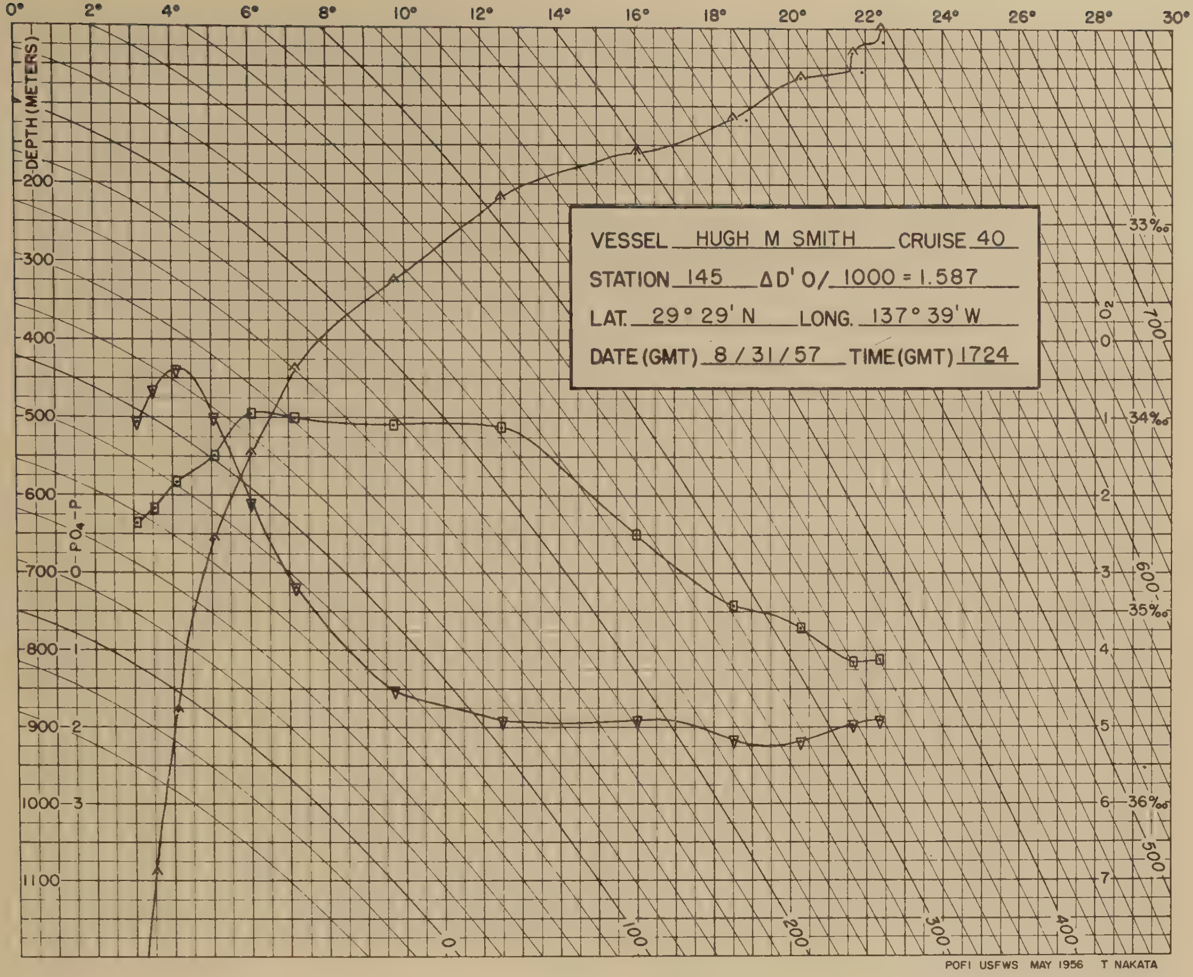
Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	21.24	34.27	402.4	5.03	-
31	20.44	34.43	370.1	5.13	-
63	17.18	34.07	317.7	5.61	-
105	14.80	33.98	273.0	5.45	-
158	12.20	33.93	226.2	5.11	-
216	10.26	33.96	190.5	4.94	-
324	7.81	34.11	142.4	3.57	-
438	6.04	34.04	124.6	1.91	-
544	5.08	34.14	106.0	1.02	-
658	4.52	34.25	91.9	0.54	-
877	4.19	34.42	75.7	0.38	-
1088	3.66	34.56	60.2	0.67	-
1303	3.26	34.63	51.2	0.92	-



VESSEL HUGH M SMITH CRUISE 40
STATION 144 ΔD'0/1000 = 1.502
LAT. 30° 14' N LONG. 135° 33' W
DATE (GMT) 8 / 31 / 57 TIME (GMT) 0426

Weather 02, cloud coverage 2. Wind: 280°, 09 kt. Sea: < 1 ft. Wire angle: 07°.
BT slide: 408. Dry bulb: 72.5°F. Wet bulb: 68.0°F. Barometric pressure: 1021 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, μg at. /L.
0	21.84	34.25	419.3	4.98	-
31	20.69	34.33	383.7	5.13	-
63	17.70	34.05	331.2	5.49	-
104	16.06	34.05	294.3	5.51	-
157	12.86	33.78	249.5	5.12	-
214	9.84	33.73	201.0	4.52	-
320	7.74	34.02	148.3	2.97	-
433	6.44	34.07	127.3	1.55	-
541	5.70	34.07	118.3	0.87	-
653	4.72	34.25	94.0	0.60	-
871	4.10	34.47	71.0	0.34	-
1086	3.52	34.56	58.8	0.70	-
1302	3.16	34.65	48.7	1.03	-

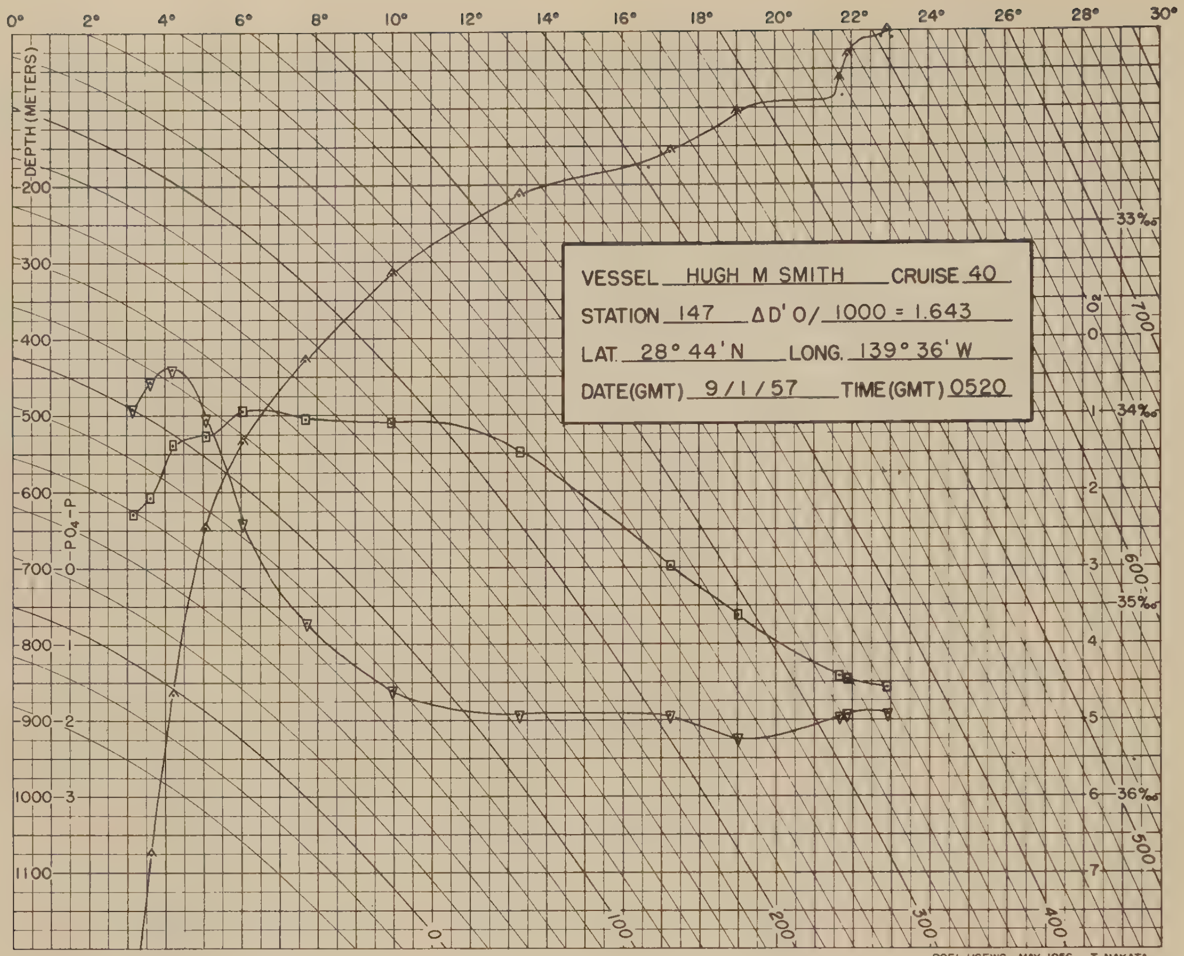


VESSEL HUGH M SMITH CRUISE 40
STATION 145 ΔD' 0/ 1000 = 1.587
LAT. 29° 29' N LONG. 137° 39' W
DATE (GMT) 8 / 31 / 57 TIME (GMT) 1724

POFI USFWS MAY 1956 T NAKATA

Weather: 03, cloud coverage 5. Wind: 280°, 09 kt. Sea: < 1 ft. Wire angle: 05°. BT slide: 412. Dry bulb: 72.9°F. Wet bulb: 68.4°F. Barometric pressure: 1023 mb.

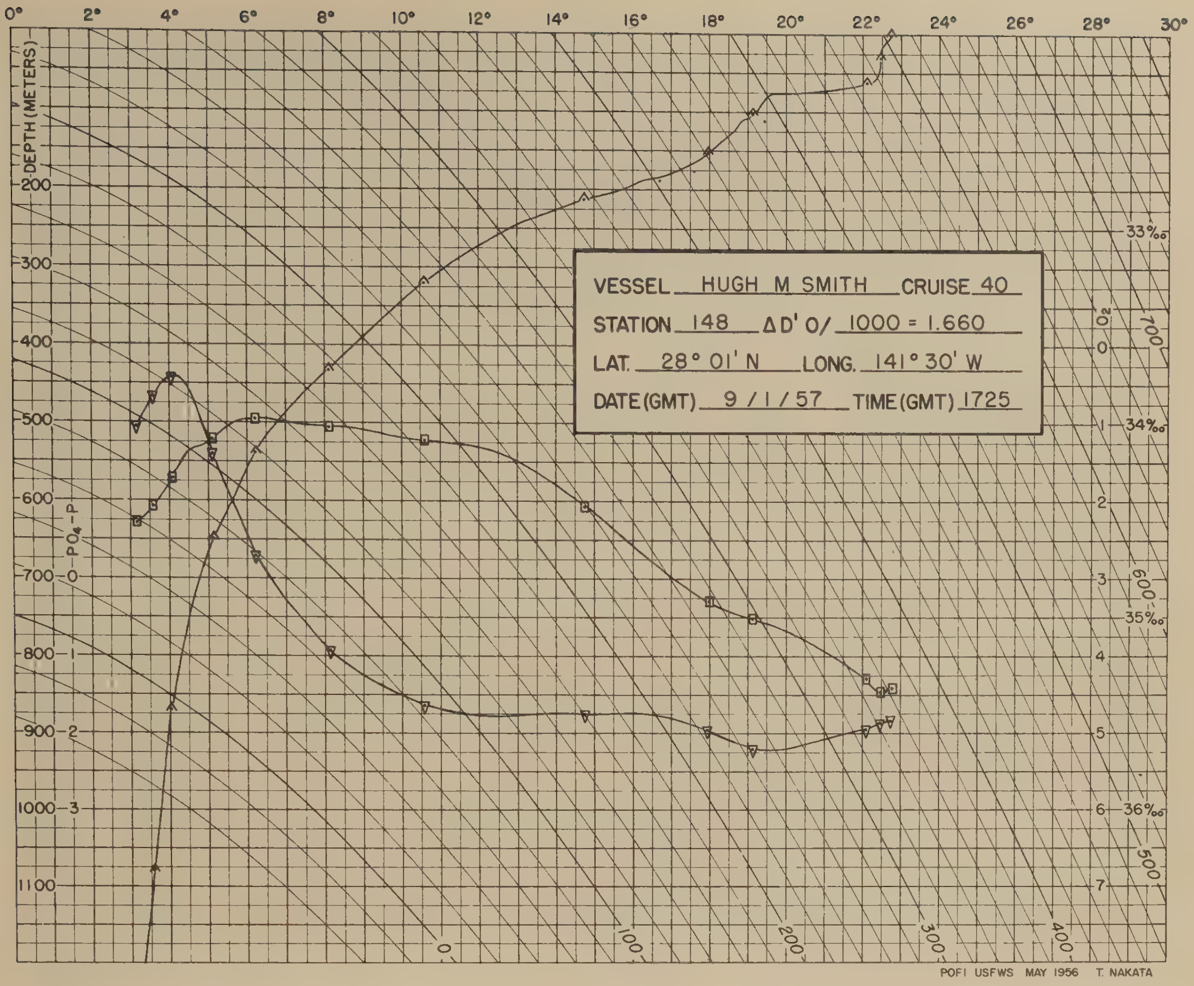
Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	22.38	35.25	361.5	4.91	-
31	21.64	35.26	341.1	4.98	-
63	20.27	35.08	318.7	5.19	-
105	18.55	34.97	284.3	5.17	-
158	16.00	34.60	253.1	4.90	-
217	12.51	34.05	223.1	4.91	-
324	9.74	34.04	176.4	4.52	-
438	7.20	34.00	142.1	3.19	-
545	6.05	33.98	129.3	2.11	-
658	5.08	34.20	101.4	1.00	-
878	4.12	34.33	81.8	0.39	-
1090	3.54	34.47	65.9	0.64	-
1305	3.12	34.54	56.7	1.05	-



POFI USFWS MAY 1956 T NAKATA

Weather: 21, cloud coverage 8. Wind: 330°, 05 kt. Sea: < 1 ft. Wire angle: 10°. BT slide: 416. Dry bulb: 73.7°F. Wet bulb: 69.0°F. Barometric pressure: 1024 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O_2, ml./L.	PO_4-P, µg at./L.
0	22.94	35.43	363.6	4.91	-
31	21.86	35.39	337.5	4.92	-
62	21.66	35.37	333.6	4.96	-
103	19.03	35.05	290.1	5.23	-
155	17.26	34.79	267.3	4.92	-
212	13.34	34.20	227.9	4.91	-
317	9.98	34.04	180.0	4.61	-
429	7.74	34.02	148.3	3.70	-
536	6.04	33.98	129.1	2.40	-
647	5.09	34.11	108.3	1.06	-
866	4.22	34.16	95.6	0.40	-
1077	3.62	34.43	69.5	0.56	-
1293	3.18	34.52	58.8	0.91	-



VESSEL HUGH M SMITH CRUISE 40

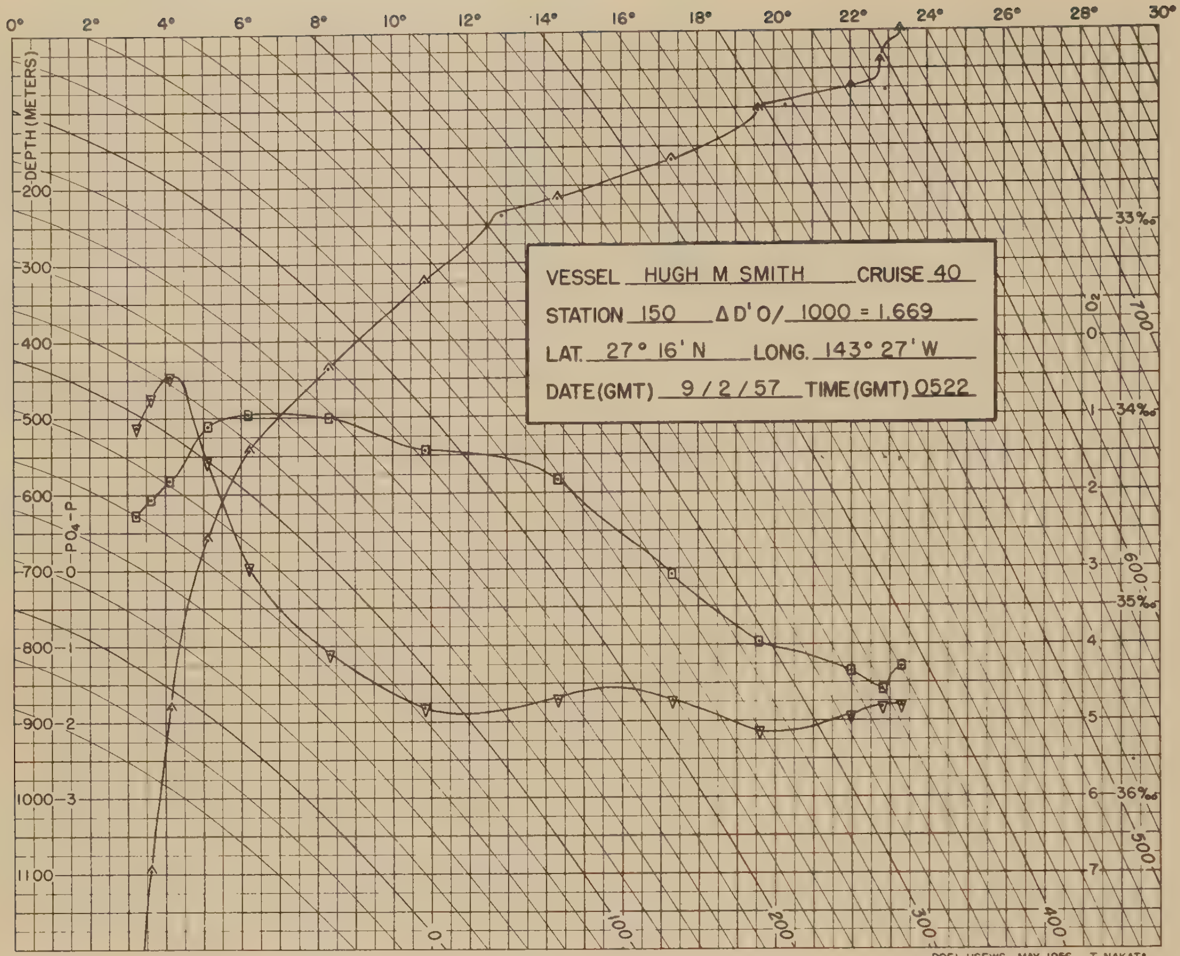
STATION 148 ΔD' 0/1000 = 1.660

LAT. 28° 01' N LONG. 141° 30' W

DATE (GMT) 9 / 1 / 57 TIME (GMT) 1725

Weather: 03, cloud coverage 4. Wind: 030°, 08 kt. Sea: < 1 ft. Wire angle: 11°.
BT slide: 420. Dry bulb: 74.9°F. Wet bulb: 69.1°F. Barometric pressure: 1023 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	22.76	35.37	363.1	4.84	-
31	22.46	35.39	353.5	4.86	-
62	22.10	35.32	348.9	4.97	-
103	19.14	35.01	295.6	5.21	-
154	17.96	34.92	273.9	4.96	-
213	14.76	34.43	239.2	4.75	-
318	10.58	34.09	186.3	4.63	-
431	8.13	34.02	153.5	3.94	-
538	6.23	33.98	131.3	2.71	-
651	5.11	34.09	110.1	1.40	-
869	4.05	34.29	84.1	0.42	-
1081	3.58	34.43	69.2	0.66	-
1292	3.16	34.52	58.5	1.05	-

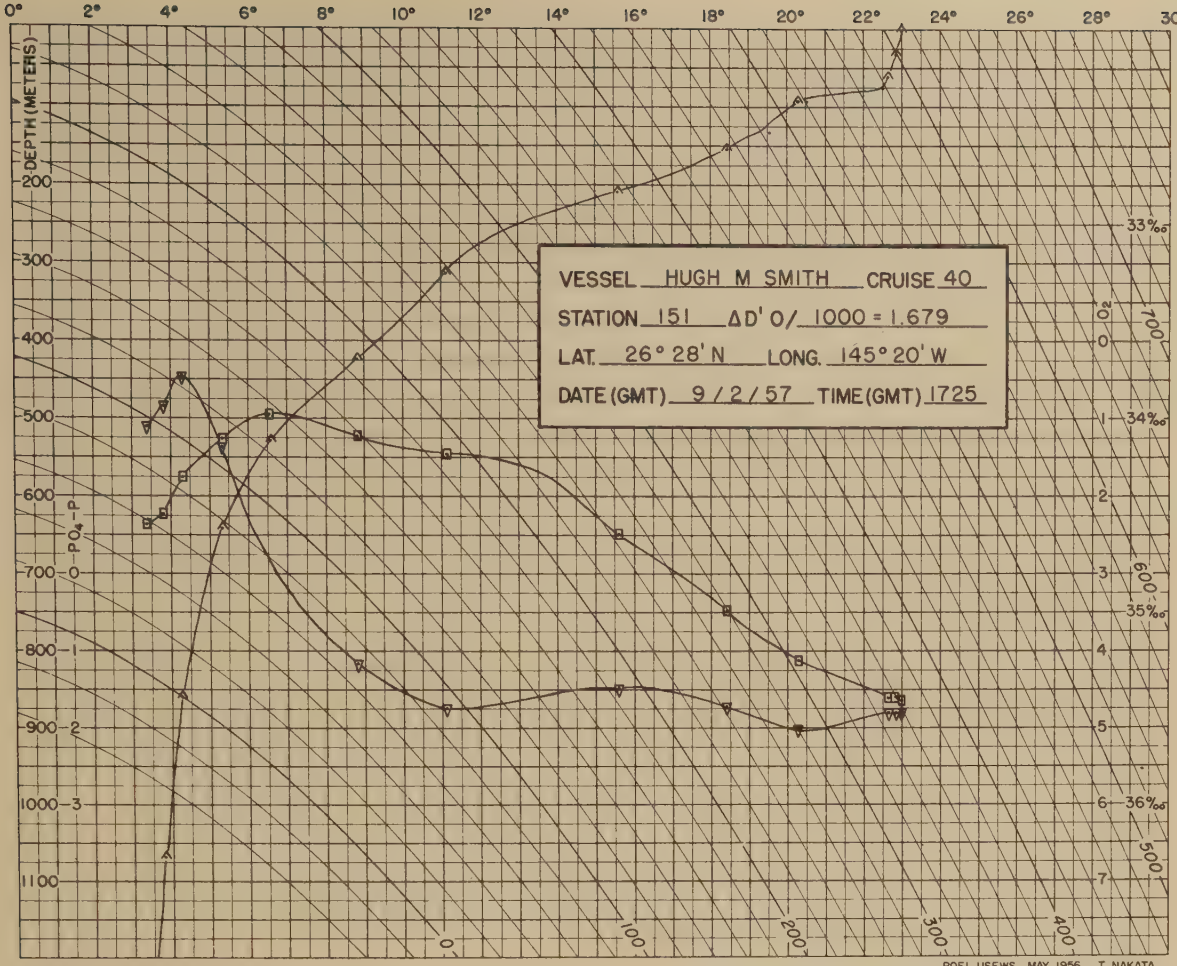


VESSEL HUGH M SMITH CRUISE 40
STATION 150 ΔD'0/1000 = 1.669
LAT. 27° 16' N LONG. 143° 27' W
DATE (GMT) 9 / 2 / 57 TIME (GMT) 0522

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 2. Wind: 050°, 10 kt. Sea: < 1 ft. Wire angle: 01°. BT slide: 424. Dry bulb: 74.0°F. Wet bulb: 69.9°F. Barometric pressure: 1022 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O_2, ml. /L.	PO_4-P, µg at. /L.
0	23.29	35.32	381.2	4.80	-
41	22.78	35.44	358.5	4.81	-
72	21.98	35.34	344.3	4.94	-
104	19.59	35.19	293.6	5.13	-
167	17.34	34.83	266.2	4.72	-
215	14.35	34.33	238.3	4.71	-
322	10.86	34.18	184.3	4.80	-
436	8.34	34.00 Q	157.9	4.09	-
545	6.22	33.98	131.2	2.95	-
659	5.12	34.05	113.3	1.58	-
881	4.13	34.33	81.8	0.44	-
1094	3.62	34.43	69.5	0.73	-
1307	3.24	34.51	60.1	1.12	-

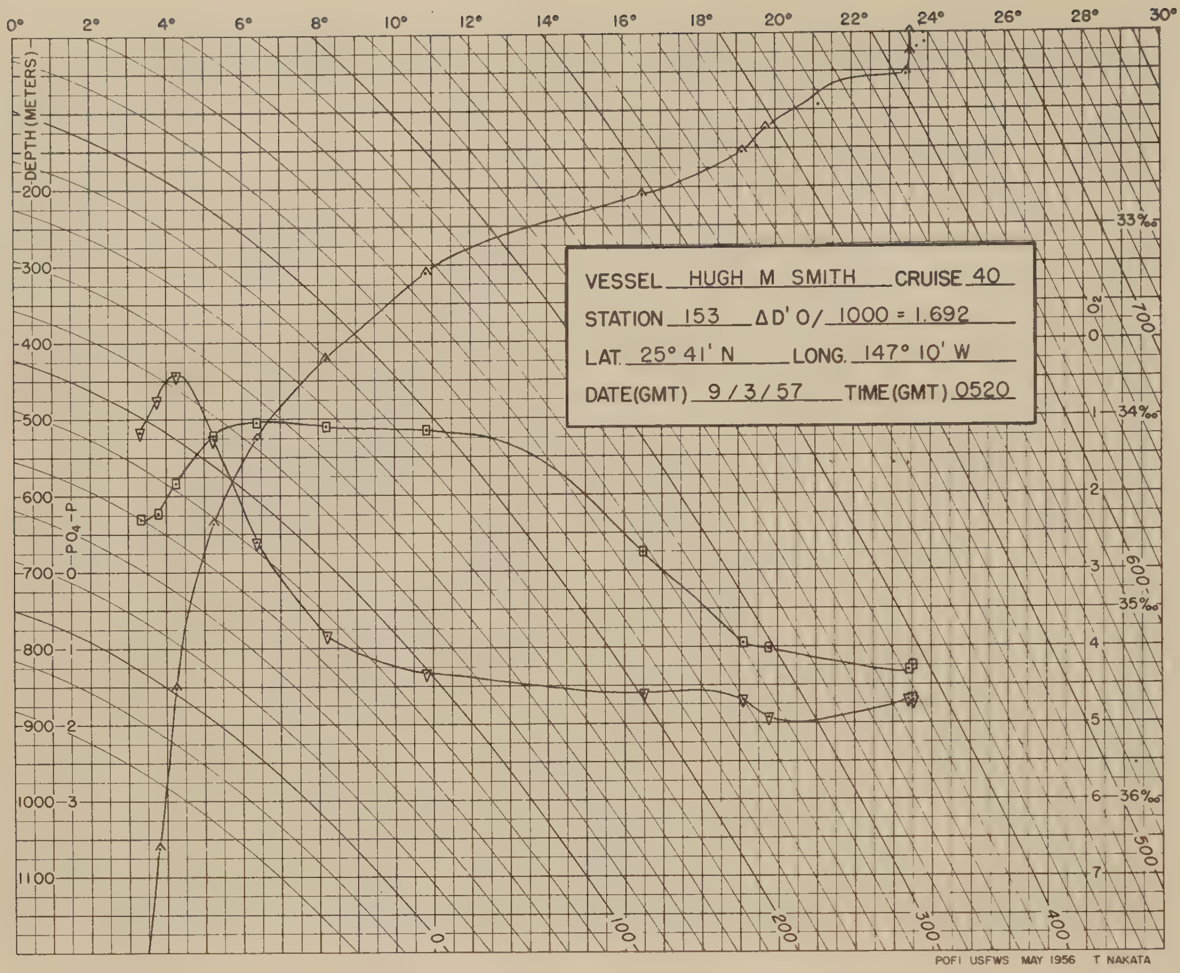


VESSEL HUGH M SMITH CRUISE 40
STATION 151 ΔD' 0/ 1000 = 1.679
LAT. 26° 28' N LONG. 145° 20' W
DATE (GMT) 9 / 2 / 57 TIME (GMT) 1725

POFI USFWS MAY 1956 T NAKATA

Weather: 21, cloud coverage 6. Wind: 050°, 05 kt. Sea: 1-3 ft. Wire angle 16°.
BT slide: 428. Dry bulb: 74.0°F. Wet bulb: 69.3°F. Barometric pressure: 1022 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	22.99	35.46	362.7	4.80	-
30	22.86	35.44	360.7	4.79	-
61	22.65	35.44	355.0	4.81	-
91	20.30	35.25	307.1	5.02	-
153	18.44	34.99	280.3	4.71	-
209	15.60	34.60	244.5	4.48	-
312	11.14	34.18	189.1	4.73	-
424	8.82	34.09	158.4	4.17	-
530	6.57	33.98	135.6	NG	-
641	5.34	34.11	111.3	1.38	-
859	4.30	34.31	85.1	0.47	-
1068	3.81	34.49	66.9	0.84	-
1283	3.38	34.54	59.1	1.10	-

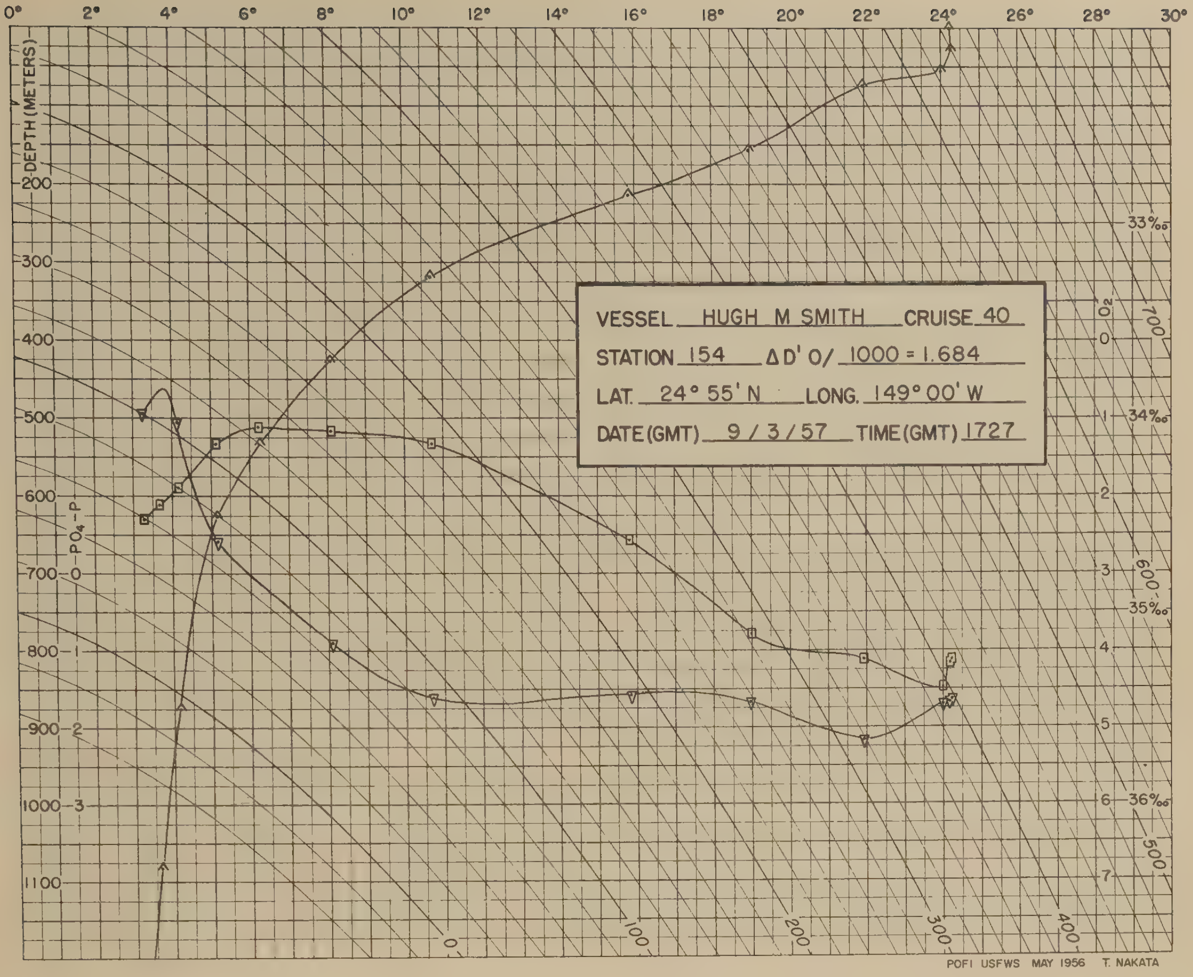


VESSEL HUGH M SMITH CRUISE 40
STATION 153 ΔD' 0/1000 = 1.692
LAT. 25° 41' N LONG. 147° 10' W
DATE(GMT) 9/3/57 TIME(GMT) 0520

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 7. Wind: 070°, 10 kt. Sea: 1-3 ft. Wire angle: 15°. BT slide: 431. Dry bulb: 75.9°F. Wet bulb: 70.9°F. Barometric pressure: 1019 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	23.54	35.30	389.6	4.71	-
25	23.52	35.30	389.0	4.67	-
51	23.42	35.32	384.9	4.69	-
122	19.76	35.21	296.3	4.90	-
152	19.11	35.17	283.3	4.68	-
209	16.50	34.70	256.6	4.59	-
310	10.84	34.05	193.5	4.32	-
421	8.21	34.04	153.3	3.82	-
527	6.39	34.02	130.3	2.61	-
637	5.26	34.09	111.8	1.24	-
852	4.26	34.33	83.1	0.42	-
1061	3.78	34.49	66.5	0.73	-
1273	3.34	34.52	60.3	1.17	-

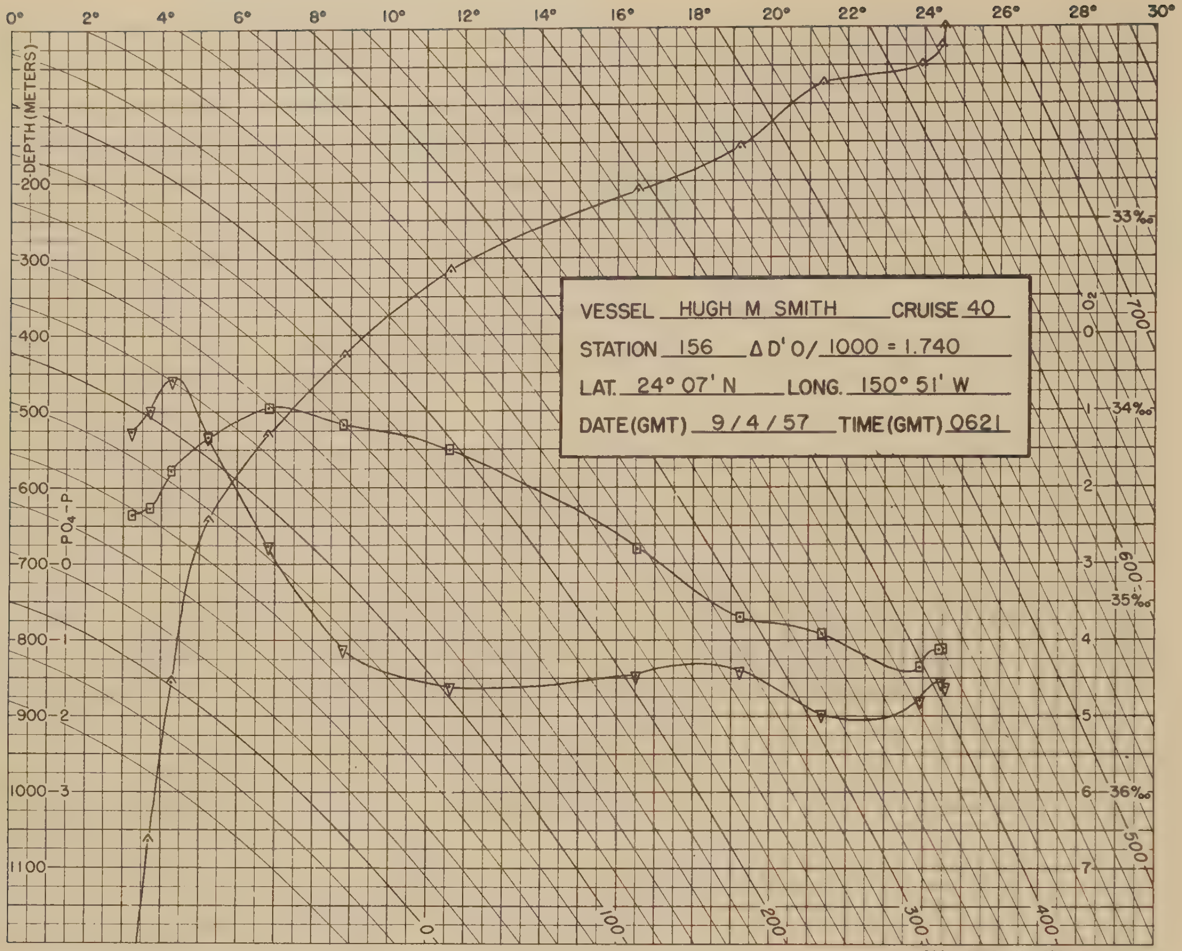


VESSEL HUGH M SMITH CRUISE 40
STATION 154 ΔD' 0/1000 = 1.684
LAT. 24° 55' N LONG. 149° 00' W
DATE (GMT) 9/3/57 TIME (GMT) 1727

POFI USFWS MAY 1956 T. NAKATA

Weather: 02, cloud coverage 6. Wind: 070°, 15 kt. Sea: 1-3 ft. Wire angle: 07°, 06°. BT slide: 435. Dry bulb: 73.8°F. Wet bulb: 71.3°F. Barometric pressure: 1019 mb.

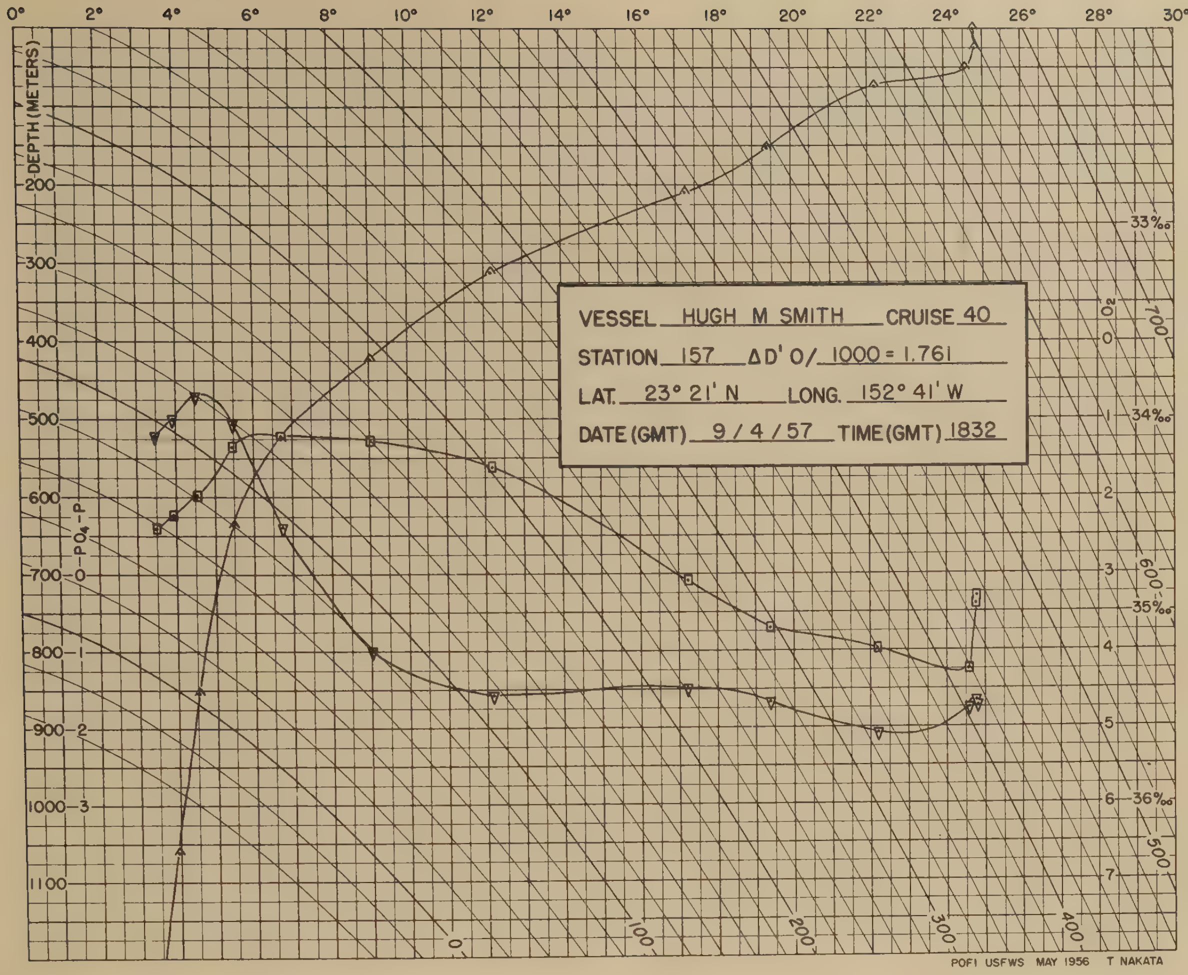
Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	24.21	35.26	411.5	4.66	-
26	24.24	35.25	413.1	4.64	-
53	24.00	35.39	396.3	4.70	-
73	21.92	35.25	349.2	5.17	-
157	18.95	35.12	283.2	4.67	-
214	15.85	34.63	247.6	4.57	-
318	10.71	34.13	185.4	4.62	-
427	8.10	34.07	149.4	3.89	-
630	5.16	34.14	107.0	2.60	-
877	4.16	34.36	80.0	1.06	-
1083	3.66	34.45	68.4	NG	-
I 1294	3.28	34.52	59.7	0.93	-
II 536	6.28	34.05	126.5	-	-



POFI USFWS MAY 1956 T NAKATA

Weather: 00, cloud coverage 6. Wind: 100°, 07 kt. Sea: < 1 ft. Wire angle: 11°. BT slide: 439. Dry bulb: 75.2°F. Wet bulb: 71.3°F. Barometric pressure: 1019 mb.

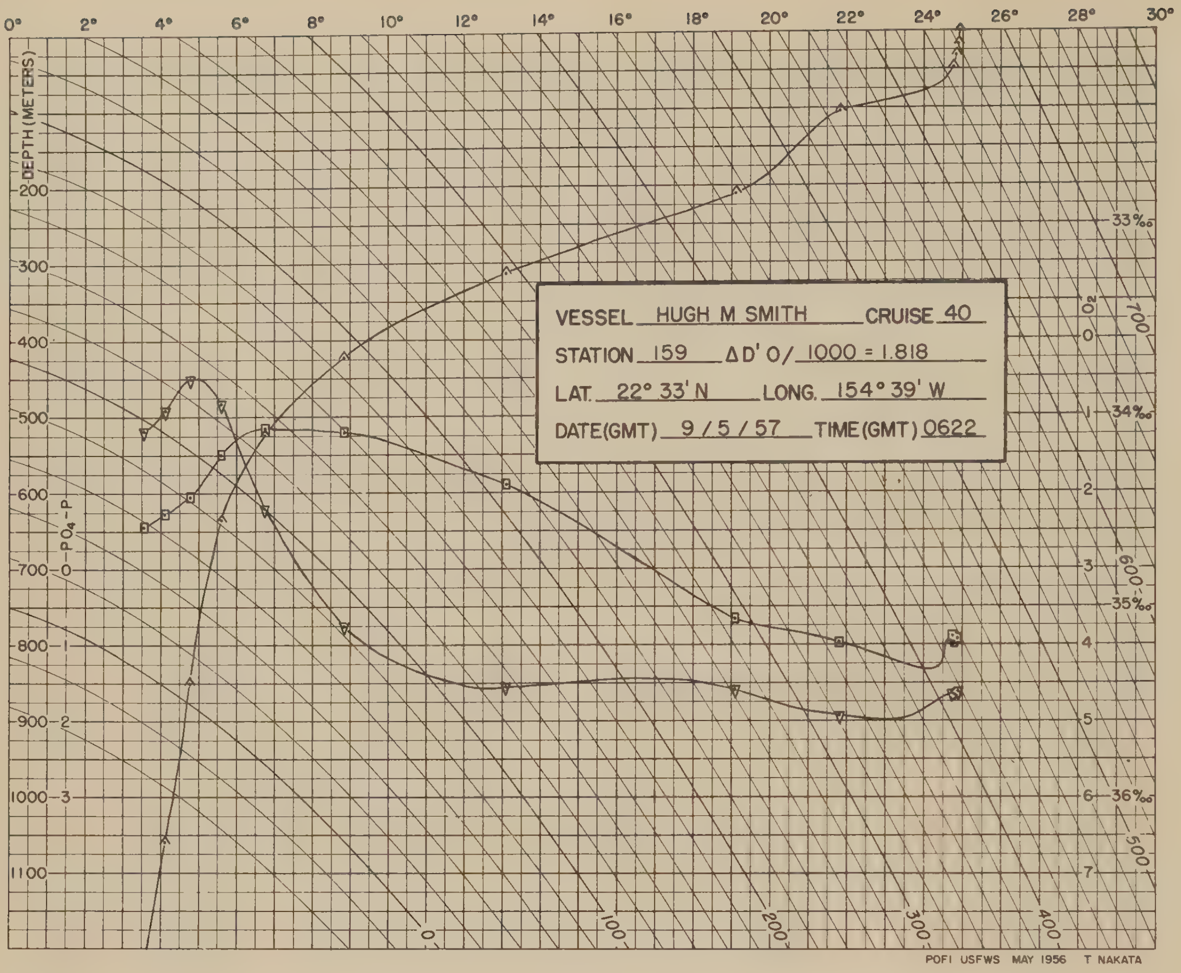
Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O2, ml. /L.	PO4-P, µg at. /L.
0	24.54	35.25	421.6	4.62	-
25	24.45	35.25	419.1	4.57	-
51	23.92	35.35	396.8	4.80	-
72	21.36	35.17	340.3	4.98	-
155	19.23	35.08	292.8	4.41	-
212	16.56	34.72	256.6	4.46	-
315	11.63	34.20	196.2	4.60	-
426	8.83	34.07	160.0	4.10	-
531	6.86	33.98	139.4	2.74	-
642	5.26	34.14	108.1	1.35	-
856	4.30	34.31	85.1	0.57	-
1063	3.72	34.51	64.4	0.98	-
1274	3.24	34.54	57.8	1.26	-



VESSEL HUGH M SMITH CRUISE 40
STATION 157 ΔD' 0/1000 = 1.761
LAT. 23° 21' N LONG. 152° 41' W
DATE (GMT) 9 / 4 / 57 TIME (GMT) 1832

Weather: 15, cloud coverage 6. Wind: 070°, 14 kt. Sea: 3-5 ft. Wire angle: 15°. BT slide: 443. Dry bulb: 76.5°F. Wet bulb: 72.8°F. Barometric pressure: 1018 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	24.80	34.92	452.9	4.73	-
25	24.78	34.96	449.4	4.67	-
51	24.59	35.30	419.5	4.76	-
72	22.20	35.19	361.0	5.07	-
153	19.40	35.08	297.0	4.67	-
210	17.24	34.83	263.9	4.49	-
312	12.20	34.25	202.5	4.58	-
421	9.04	34.11	160.3	4.00	-
525	6.74	34.09	129.5	2.39	-
636	5.47	34.14	110.4	1.05	-
853	4.56	34.38	82.5	0.69	-
1061	3.92	34.49	67.9	0.99	-
1275	3.47	34.56	58.3	1.19	-



VESSEL HUGH M SMITH CRUISE 40

STATION 159 ΔD' 0/ 1000 = 1.818

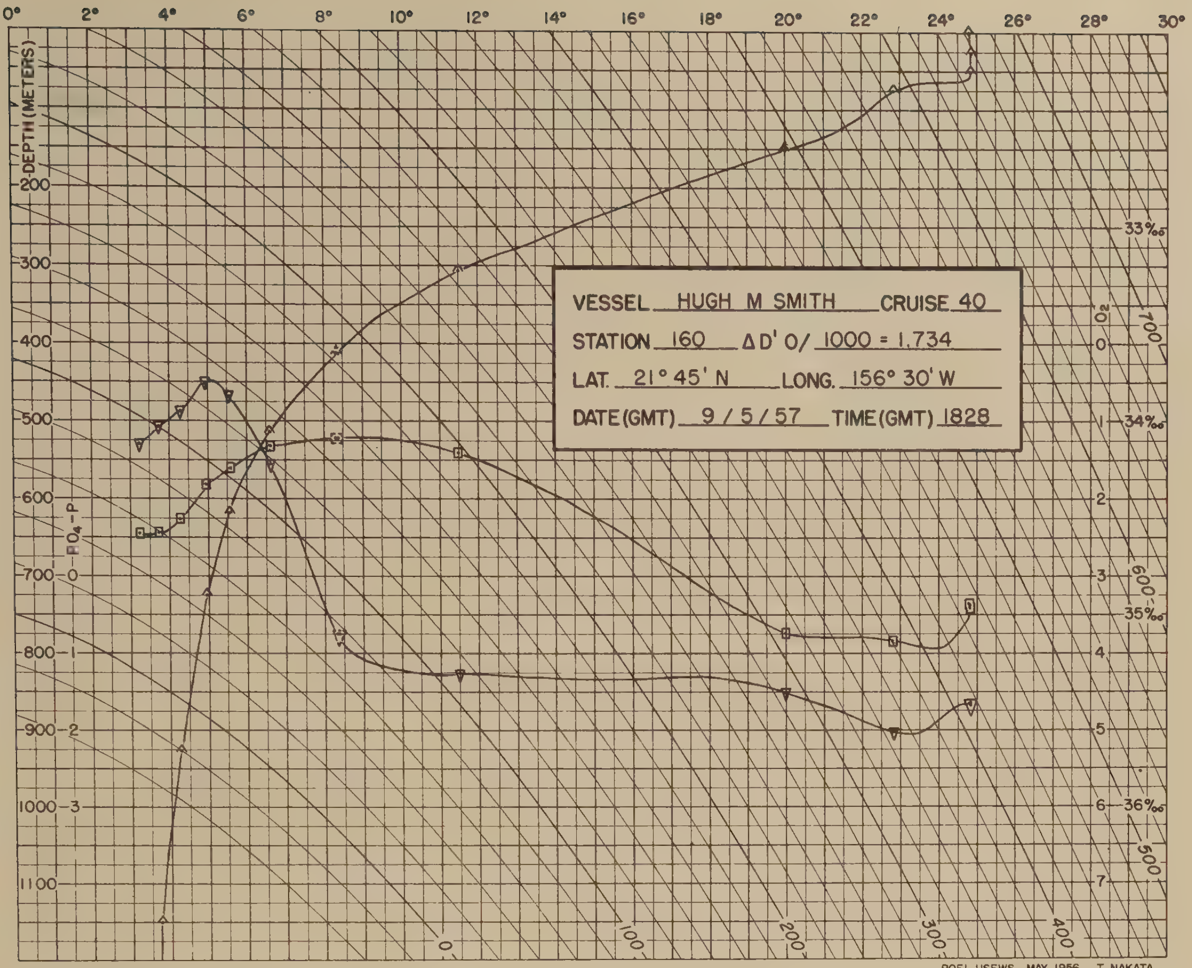
LAT. 22° 33' N LONG. 154° 39' W

DATE(GMT) 9 / 5 / 57 TIME(GMT) 0622

POFI USFWS MAY 1956 T NAKATA

Weather: 02, cloud coverage 2. Wind: 060°, 07 kt. Sea: 1-3 ft. Wire angle: 15°. BT slide: 447. Dry bulb: 77.4°F. Wet bulb: 70.9°F. Barometric pressure: 1017 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl./ton	O2, ml./L.	PO4-P, µg at./L.
0	24.90	35.17	437.7	4.63	-
15	24.89	35.16	438.2	4.62	-
31	24.82	35.19	434.1	4.66	-
46	24.76	35.16	434.4	4.63	-
102	21.82	35.19	350.9	4.92	-
210	19.14	35.07	291.3	4.59	-
313	13.12	34.36	211.7	4.55	-
423	8.86	34.09	159.0	3.76	-
527	6.76	34.07	131.2	2.21	-
637	5.62	34.20	107.8	0.84	-
852	4.79	34.42	81.7	0.51	-
1058	4.14	34.51	68.5	0.92	-
1266	3.56	34.58	57.8	1.19	-



VESSEL HUGH M SMITH CRUISE 40
STATION 160 ΔD' 0/1000 = 1.734
LAT. 21° 45' N LONG. 156° 30' W
DATE (GMT) 9 / 5 / 57 TIME (GMT) 1828

POFI USFWS MAY 1956 T. NAKATA

Weather: 03, cloud coverage 8. Wind: 090°, 18 kt. Sea: 3-5 ft. Wire angle: 20°. BT slide: 450. Dry bulb: 76.6°F. Wet bulb: 72.2°F. Barometric pressure: 1016 mb.

Depth, m.	T, °C.	S, °/oo	δ t, cl. /ton	O_2, ml. /L.	PO_4-P, µg at. /L.
0	24.80	34.94	451.4	4.67	-
25	24.84	34.96	451.1	4.68	-
50	24.84	34.97	450.4	4.65	-
75	22.82	35.14	381.2	5.03	-
151	20.00	35.10	310.5	4.52	-
307	11.52	34.16	197.2	4.27	-
413	8.34	34.09	151.4	3.75	-
514	6.65	34.13	125.3	1.55	-
619	5.57	34.25	103.4	0.68	-
725	4.96	34.33	90.3	0.51	-
928	4.29	34.51	69.9	0.88	-
1152	3.74	34.58	59.4	1.07	-
1367	3.25	34.58	54.9	1.30	-

JOHN C [illegible] R

Northeastern Pacific Albacore Survey
Part 1. Biological Observations

SPECIAL SCIENTIFIC REPORT—FISHERIES NO. 310

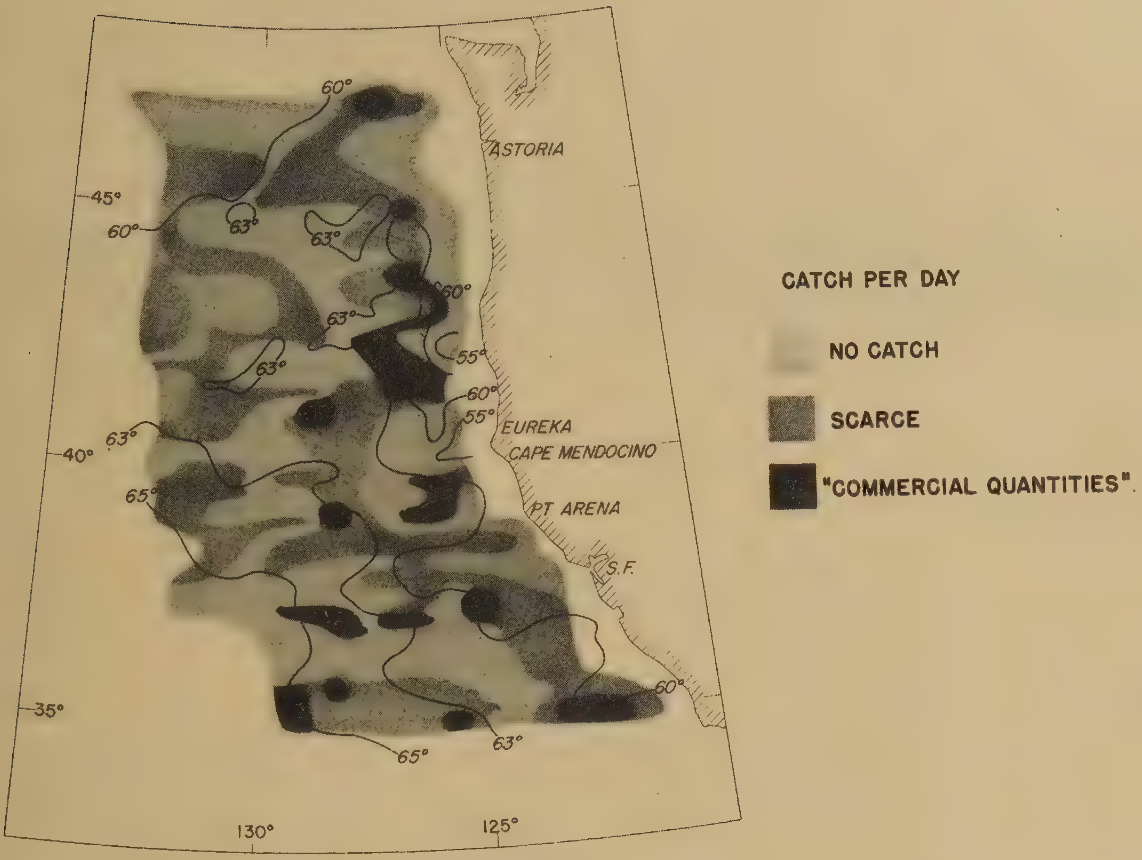
UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State or cooperating Agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Fred A. Seaton, Secretary

Fish and Wildlife Service, Arnie J. Suomela, Commissioner


60°
ASTORIA
45°
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55°
EUREKA
CAPE MENDOCINO
63°
40°
65°
PT ARENA
S.F.
60°
35°
63°
65°
130°
125°
CATCH PER DAY
NO CATCH
SCARCE
"COMMERCIAL QUANTITIES".

NORTHEASTERN PACIFIC ALBACORE SURVEY

PART 1. BIOLOGICAL OBSERVATIONS

By

Joseph J. Graham
Fishery Research Biologist
Bureau of Commercial Fisheries
Biological Laboratory
Honolulu, Hawaii

Special Scientific Report--Fisheries No. 310

WASHINGTON: JULY 1959

ABSTRACT

This report lists the biological data collected aboard research vessels *Hugh M. Smith* and *Joh* *R. Manning* and nine chartered commercial vessels during the Northeastern Pacific Albacore Surve (NEPAS). The survey was developed to map the distribution of albacore in the northern area of th United States west coast albacore fishery during the summer of 1957.

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Frontispiece: Chart showing relative abundance of albacore during NEPAS

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NORTHEASTERN PACIFIC ALBACORE SURVEY
PART 1. BIOLOGICAL OBSERVATIONS

By

Joseph J. Graham
Fishery Research Biologist
Bureau of Commercial Fisheries
Biological Laboratory[1]
Honolulu, Hawaii

Albacore tuna, Germo alalunga (Bonnaterre) vere landed commercially in ports of Washingon and Oregon for the first time in 1937. Durng 1939 they began to appear in exploratory atches of commercial vessels off British olumbia, Canada. By 1945 the annual commerial catch exceeded a million pounds. Large atches were consistently made off British olumbia by 1948 with good fishing extending as ar north as Queen Charlotte Islands (Powell et l. 1952), which represented the farthest northard extension of the fishery. Following 1948 he fishery declined rapidly; by 1951 only a few lbacore were taken commercially north of alifornia.

The return of albacore to these northern aters was indicated in 1955 when scattered fish ere reported from the area by research vesels of the University of Washington and of the Jnited States Fish and Wildlife Service (Graham 957, Holmberg 1955). In 1956, vessels from hese agencies again reported fish in the area nd commercial vessels, which followed up hese reports, developed a small albacore fishry off Oregon (Anonymous 1956, Frolander and incoln 1956).

The Northeastern Pacific Albacore Survey r NEPAS was designed to map the distribution f albacore in this northern area and to deternine how the distribution was related to oceanoraphic and biological phenomena. The survey as conducted by the Biological Laboratory of he Bureau of Commercial Fisheries at Honolulu, Iawaii, as a part of their Saltonstall-Kennedy 68 Stat. 376) albacore tuna project, and in coperation with members of the fishing industry, nd the fishery research agencies of California, regon, and Washington. The Pacific Marine isheries Commission acted as liaison for the ooperating agencies.

The survey area extended from 35°N. to 7°N. latitude and from 50 to 350 miles offshore. he southern limit of the survey area was just north of Point Arguello, California, which approximates the northern summer limit of the southern California albacore fishery. The northern limit approached generally the northernmost penetration of the west coast albacore fishery during the summer. Inshore and offshore limits were determined from data gathered on previous cruises which indicated that a definite scarcity of fish existed beyond these boundaries during the summer (Graham 1957, Anonymous 1957). Thus, the survey was placed off the coasts of northern California, Oregon, and Washington. The period covered was from July 22 to August 1 (1957), a time when the west coast albacore fishery could be expected to reach or approach its peak in production (Clemens 1955).

Nine charter vessels were assigned to the trolling tracks shown in figure 1. Six of the vessels carried scientific observers provided by California Fish and Game (2), Oregon Fish Commission (1), Washington State Department of Fisheries (1), and Honolulu Biological Laboratory (2). The vessels, operators, home ports, and names and agencies of the observers are given in table 1. The charter vessels were augmented by the two Honolulu Laboratory vessels, the Hugh M. Smith and the John R. Manning, which operated in the survey area making oceanographic and biological observations.

This report lists the biological data collected during the survey. They are presented here to make them readily available to other agencies studying the ecology of the albacore in the eastern Pacific. Descriptive and analytical publications will follow. Oceanographic and plankton data will also be the subjects of separate reports.

The John R. Manning departed on cruise 36 from Honolulu on June 14, 1957, to make a preliminary troll and gill-net survey of the area. The Manning travelled northeast to 42°N., 135°W. (see fig. 2), returned south to 31°N., and then zigzagged northward through the NEPAS area. The Manning arrived in Astoria, Oregon, on July 16 and remained there until the start of NEPAS on July 22. Subsequently, she proceeded

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[1] Formerly the Pacific Oceanic Fishery nvestigations.

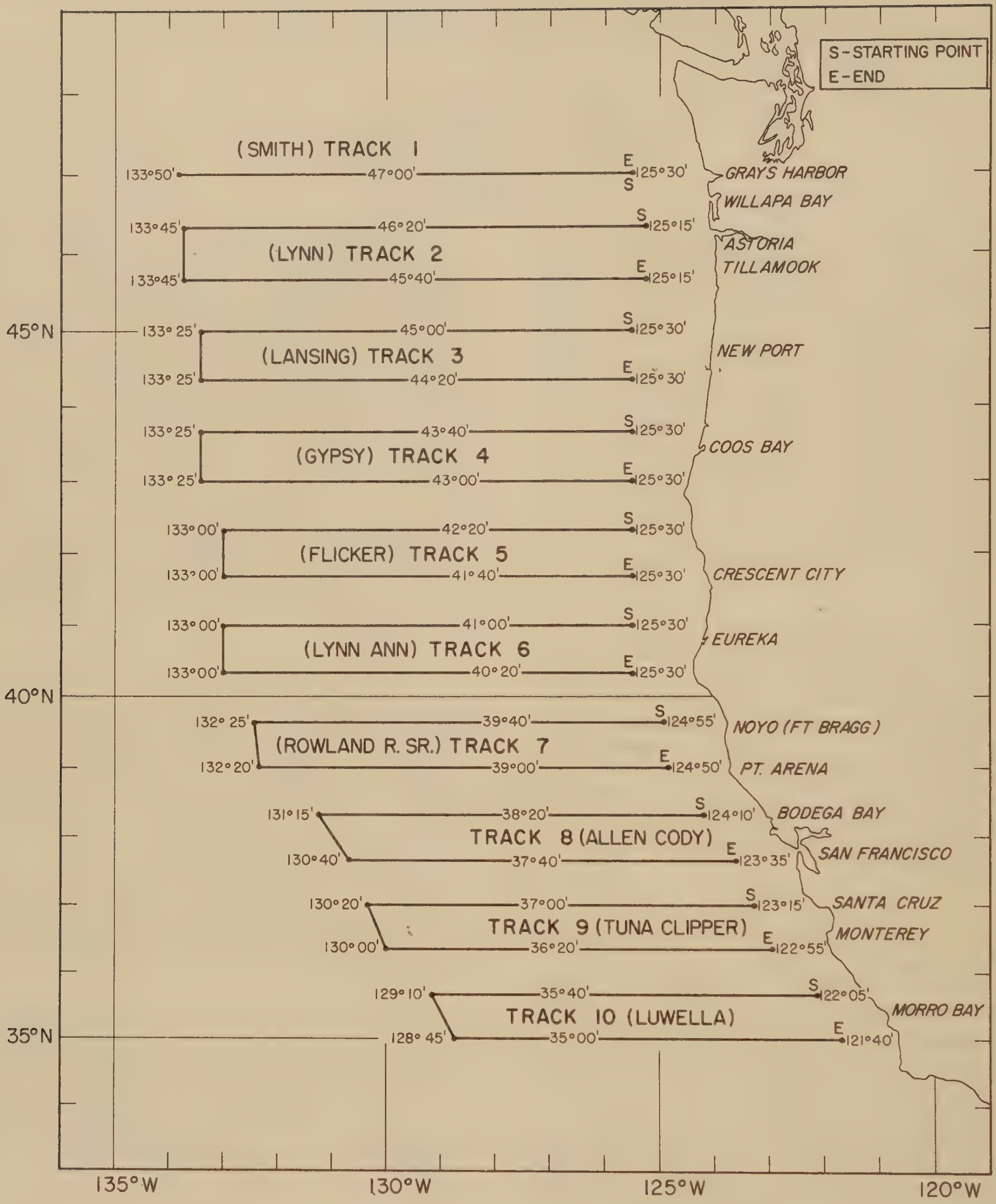
S-STARTING POINT
E-END
(SMITH) TRACK 1
133°50'
47°00'
E 125°30' S
(LYNN) TRACK 2
133°45'
46°20'
S 125°15'
133°45'
45°40'
E 125°15'
(LANSING) TRACK 3
133° 25'
45°00'
S 125°30'
133° 25'
44°20'
E 125° 30'
(GYPSY) TRACK 4
133°25'
43°40'
S 125°30'
133° 25'
43°00'
E 125°30'
(FLICKER) TRACK 5
133°00'
42°20'
S 125°30'
133°00'
41°40'
E 125°30'
(LYNN ANN) TRACK 6
133°00'
41°00'
S 125°30'
133°00'
40°20'
E 125°30'
(ROWLAND R. SR.) TRACK 7
132° 25'
39°40'
S 124°55'
132°20'
39°00'
E 124°50'
TRACK 8 (ALLEN CODY)
131°15'
38°20'
S 124°10'
130°40'
37°40'
E 123°35'
TRACK 9 (TUNA CLIPPER)
130°20'
37°00'
S 123°15'
130°00'
36°20'
E 122°55'
TRACK 10 (LUWELLA)
129°10'
35°40'
S 122°05'
128° 45'
35°00'
E 121°40'
GRAYS HARBOR
WILLAPA BAY
ASTORIA
TILLAMOOK
NEW PORT
COOS BAY
CRESCENT CITY
EUREKA
NOYO (FT BRAGG)
PT. ARENA
BODEGA BAY
SAN FRANCISCO
SANTA CRUZ
MONTEREY
MORRO BAY
45°N
40°N
35°N
135°W
130°W
125°W
120°W

Figure 1.--Proposed trolling tracks for NEPAS and the names of the vessels assigned.

south through the NEPAS area, transferring equipment to the charter vessels, and then crossed into and out of the coastal band of cold water, and checked areas where the charter vessels reported good catches. The Manning returned to Honolulu August 20, 1957.

The Hugh M. Smith departed from Honolulu on cruise 40 on July 1, 1957, to run a line o oceanographic stations between Oahu anc 38°35'N., 143°28'W. (see fig. 3). The Smit then conducted an oceanographic and trollin survey between 40°N. and 46°N. and arrive

Table 1.--NEPAS charter vessel data

Name	Owner[1]	Home port	Scientific observer aboard	Organization
Allen Cody	Hunter and Foland (L. L. Newton, operator)	Fields Landing, California	Howard O. Yoshida	Honolulu Biological Laboratory
Flicker	Gus Wagner	Newport, Oregon	George Miller	Oregon Fish Commission
Gypsy	Jim Lyons	Seattle, Washington	William Stickley	Washington Department of Fisheries
Lancing	Oscar Knudsen	Seattle, Washington	None	-
Lynn	Les Withee (Josh Bufton, operator)	Garibaldi, Oregon	None	-
Lynn Ann	Herman Foland	Fields Landing, California	Thomas S. Hida	Honolulu Biological Laboratory
Luwella	O. James Bardeau	San Diego, California	Tom Jow	California Department of Fish and Game
Rowland R. Sr.	William R. Roland	El Cerrito, California	None	-
Tuna Clipper	Erling Kolnes (Floyd M. Rhoades, operator)	San Pedro, California	Robert L. Caldwell	California Department of Fish and Game

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[1] Except where operators are indicated, vessels were operated by the owners.

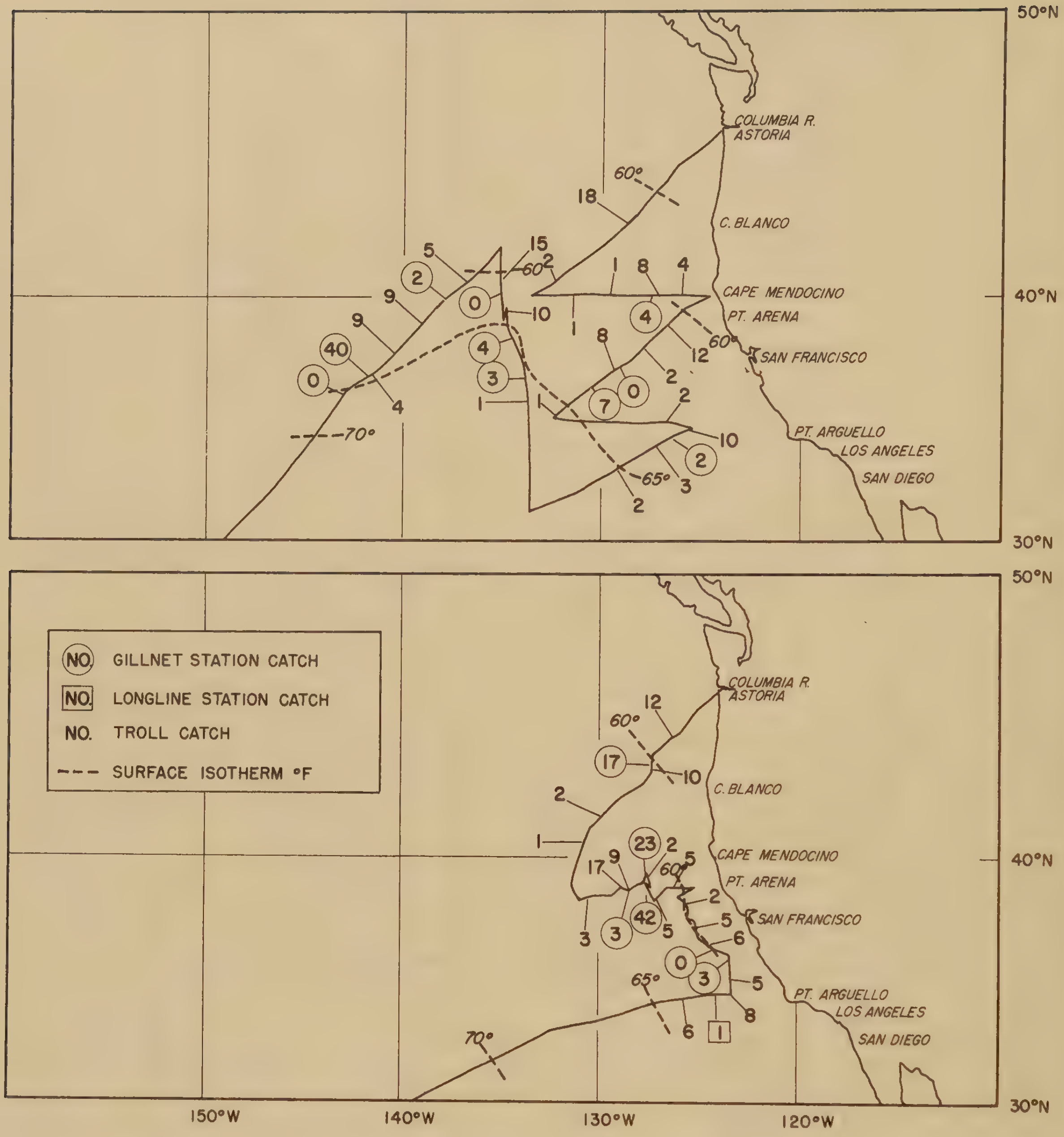
50°N
COLUMBIA R.
ASTORIA
60°
18
C. BLANCO
15
2
60°
5
2
0
9
9
40
0
4
10
1
8
4
4
CAPE MENDOCINO
PT. ARENA
60°
12
SAN FRANCISCO
4
3
1
8
7
0
2
2
10
2
3
65°
2
70°
PT. ARGUELLO
LOS ANGELES
SAN DIEGO
40°N
30°N
50°N
GILLNET STATION CATCH
LONGLINE STATION CATCH
TROLL CATCH
SURFACE ISOTHERM °F
12
60°
17
10
2
1
23
2
5
17
9
60°
2
5
3
3
42
5
6
0
3
5
65°
8
6
1
70°
40°N
30°N
150°W
140°W
130°W
120°W

Figure 2.--Albacore tuna catches made with trolling gear, gill nets, and longline by the John R. Manning (cruise 36) during the Northeastern Pacific Albacore Survey. Upper panel shows catches on track outbound from Honolulu and lower panel shows catches on track outbound from Astoria, Oregon.

in Astoria, Oregon, on July 18. During the period July 22 to August 15, the Smith acted as coordinating vessel for the NEPAS survey, completed the northernmost trolling track of NEPAS, conducted an oceanographic and trolling survey of the NEPAS area, and adjusted her track to cover areas which had been assigned to vessels forced to withdraw from the survey. After a stop for repairs a Oakland, California, from August 15-26, 195 the Smith completed the oceanographic an trolling survey of the NEPAS area an departed for Honolulu on August 29, aga occupying a line of oceanographic stations e route. She returned to Honolulu on September 1957.

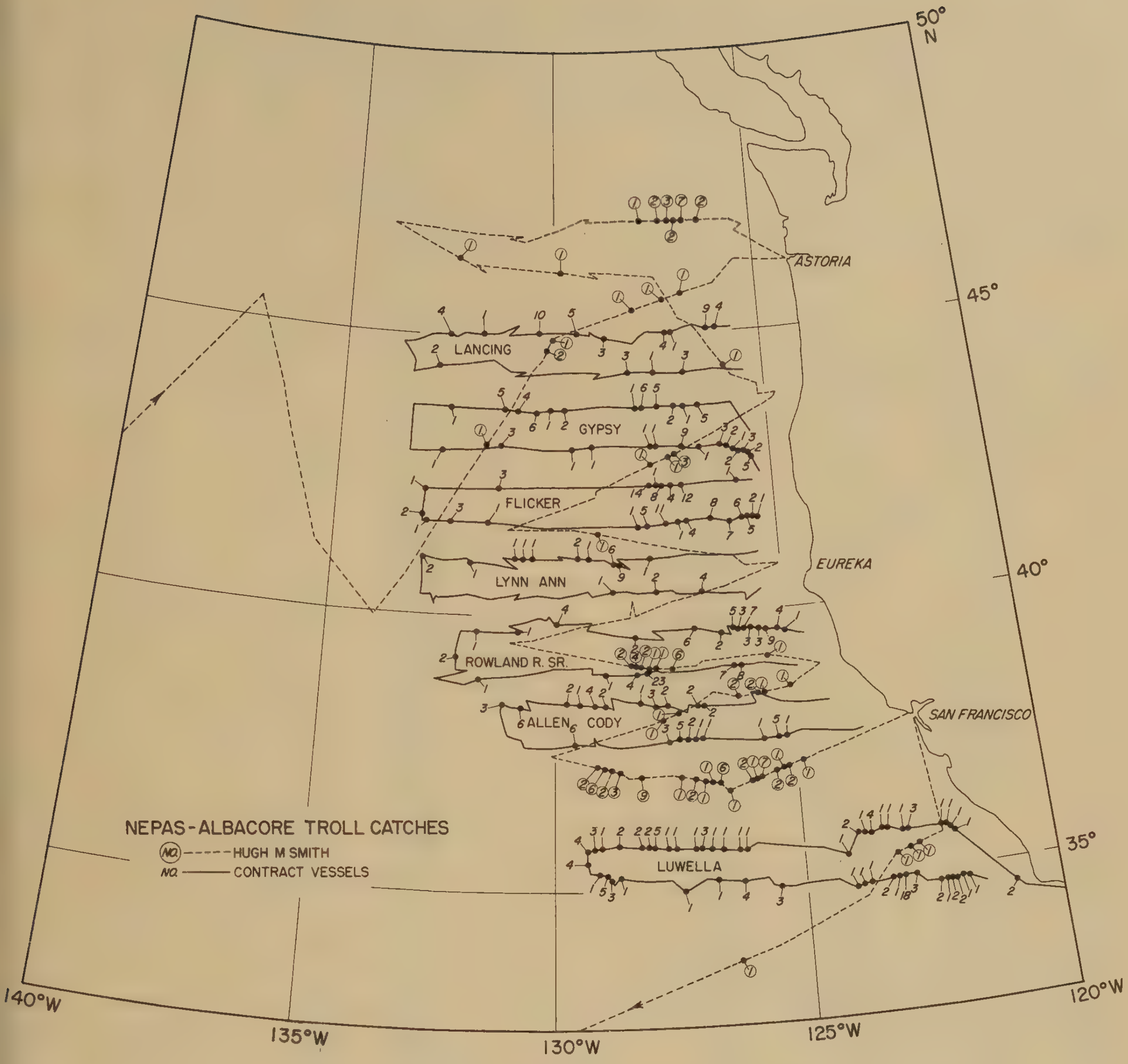
50° N
45°
40°
35°
140°W
135°W
130°W
125°W
120°W
ASTORIA
EUREKA
SAN FRANCISCO
LANCING
GYPSY
FLICKER
LYNN ANN
ROWLAND R. SR.
ALLEN
CODY
LUWELLA
NEPAS-ALBACORE TROLL CATCHES
(NO.)-----HUGH M SMITH
NO. ———CONTRACT VESSELS

Figure 3.--Albacore tuna catches by the Hugh M. Smith and the charter vessels during the Northeastern Pacific Albacore Survey.

Eight of the charter vessels started the NEPAS survey on schedule on July 22, 1957; the ninth started on July 23. All vessels completed the survey of their assigned tracks on either July 31 or August 1 except the Tuna Clipper and the Lynn. The fresh-water supply of the Lynn became contaminated with salt water and she was forced to withdraw from the survey about 150 miles from her starting point. The Tuna Clipper encountered heavy weather at the start of the survey and was forced to return to port in a leaking condition after completing 30 miles of her track. Several of the other vessels sustained storm damage (e. g., the Luwella broke both trolling booms and her radio antenna), but they were able to make repairs en route and complete their tracks.

RESULTS OF FISHING

Trolling

Charter vessels trolled 6 to 12 lines at speeds generally varying from 5 to 7 knots. Daylight trolling along the tracks was continuous; the vessels drifted at night. The Smith trolled 5 lines and the *Manning* 6 to 9 lines at speeds of 5 to 7 knots when in the survey area. A variety of jigs and feathered lures was used by all vessels. The troll catches of albacore are presented in tables 2, 3, and 4 and figures 2 and 3. Catch positions were not available for the charter vessel *Lynn*.

Albacore taken in viable condition on the troll lines were tagged and released. Charter vessels employed the California type G tag (Wilson 1953); *Smith* and *Manning* alternated the use of this tag with a new dart tag (Yamashit and Waldron 1958). The tagging results from each vessel are summarized in table 5. To date, 5 recoveries have been made (Otsu MS)[2]

Table 2.--Albacore troll catch, *Hugh M. Smith* (cruise 40)

Date 1957	Zone time[1]	Position North latitude	Position West longitude	Number of fish	Fork length (cm.)			
7/15	1225	43°04'	131°34'	1	66.5			
7/16	1100	44°47'	130°04'	2	65.0,	75.0		
	1340	44°57'	130°01'	1	79.0			
7/17	0505	45°25'	128°08'	1	67.0			
	1110	45°38'	127°21'	1	68.0			
	1451	45°43'	126°51'	1	67.0			
7/22	1300	47°00'	126°18'	2	75.0,	80.0		
	1550	47°02'	126°35'	2	67.0,	68.0		
	1710	47°02'	126°40'	1	73.1			
	1740	47°02'	126°43'	2	65.4,	-		
	1805	47°02'	126°46'	2	62.2,	66.9		
	1915	47°02'	126°57'	2	65.3,	66.6		
	2045	47°02'	127°06'	1	77.8			
7/23	0505	47°00'	127°06'	2	71.1,	78.9		
	0602	47°00'	127°13'	1	79.3			
	0715	47°00'	127°18'	1	78.0			
	1140	47°01'	127°46'	1	64.9			
7/25	1630	46°22'	132°22'	1	64.8			
7/27	1455	46°05'	129°50'	1	76.5			
7/29	1308	44°20'	125°54'	1	67.3			
7/31	0600	42°48'	127°13'	3	53.8,	54.2,	82.1	
	0715	42°44'	127°23'	1	61.9			
	1110	42°36'	127°50'	1	64.8			
8/2	1545	41°23'	129°08'	1	71.4			
8/8	0525	39°03'	128°25'	2	76.5,	79.5		
	0725	39°01'	128°12'	4	67.1,	68.0,	68.0,	81.6
	0747	39°00'	128°09'	2	65.1,	68.0		
	0930	39°00'	127°58'	1	63.1			
	1005	38°50'	127°55'	1	63.2			
	1610	39°04'	127°31'	3	54.8,	54.8,	65.2	
	1640	39°04'	127°28'	3	52.4,	59.2,	69.7	
8/9	1447	39°09'	125°27'	1	57.5			
8/10	1107	38°37'	125°00'	1	69.2			
	1522	38°31'	125°30'	1	69.6			
	1620	38°30'	125°35'	2	74.5,	81.0		
	1915	38°26'	126°00'	1	66.3			
	1929	38°26'	126°02'	1	78.0			
8/11	0925	38°11'	127°24'	1	56.3			
	1335	38°02'	127°50'	1	65.5			

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[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

[2] Otsu, T. MS. Albacore migration and growth in the North Pacific Ocean as estimated from tag recoveries. Biological Laboratory, Honolulu.

Table 2.--Albacore troll catch, Hugh M. Smith (cruise 40) (cont'd)

ate 957	Zone time 1/	Position North latitude	Position West longitude	Number of fish	Fork length (cm.)				
/12	1450	37°16'	129°08'	2	60.4,	64.6			
	1515	37°16'	129°06'	4	65.6,	69.0,	- ,	-	
	1610	37°15'	129°01'	1	54.9				
	1626	37°15'	129°00'	1	55.5				
	1653	37°14'	128°57'	1	53.3				
	1745	37°11'	128°47'	1	53.4				
	1855	37°10'	128°43'	1	-				
	1930	37°10'	128°42'	2	67.3,	67.3			
/13	0640	37°02'	128°18'	4	67.2,	70.3,	70.3,	-	
	0700	37°02'	128°15'	5	69.8,	70.3,	78.6,	83.4,	83.4
	1340	37°01'	127°26'	1	65.3				
	1535	36°57'	127°11'	2	- ,	-			
	1655	36°56'	126°57'	1	65.2				
	1755	36°54'	126°51'	1	65.9				
	1920	36°52'	126°38'	1	66.2				
	1935	36°52'	126°36'	5	66.3,	66.8,	66.8,	- ,	-
/14	0555	36°48'	126°20'	1	57.4				
	0920	36°53'	125°58'	2	79.5,	81.1			
	0935	36°53'	125°57'	1	-				
	1000	36°57'	125°49'	1	67.1				
	1025	36°56'	125°45'	4	65.3,	65.3,	67.3,	70.8	
	1040	36°56'	125°44'	1	78.9				
	1052	36°57'	125°42'	1	77.4				
	1250	37°00'	125°27'	2	64.4,	70.0			
	1442	37°03'	125°10'	1	75.0				
	1600	37°05'	125°09'	2	64.4,	69.4			
	1808	37°08'	124°53'	1	67.7				
/27	0825	35°29'	122°40'	1	-				
	0945	35°25'	122°50'	1	78.9				
	1215	35°19'	123°07'	1	79.5				
/28	1150	33°39'	126°22'	1	85.4				

Table 3.--Albacore troll catch, John R. Manning (cruise 36)

ate 957	Zone time 1/	Position North latitude	Position West longitude	Number of fish	Fork length (cm.)			
/19	1615	36°52'	142°44'	2	64.5,	66.3		
	1630	36°52'	142°44'	1	65.4			
	1635	36°52'	142°44'	1	65.6			
/20	1925	37°55'	140°20'	3	63.0,	66.1,	66.6	
	1930	37°55'	140°20'	4	64.6,	65.5,	67.4,	66.9
	1940	37°55'	140°20'	1	64.6			
	2005	37°55'	140°20'	1	63.9			
/21	0655	38°44'	139°20'	1	64.5			
	0745	38°49'	139°15'	2	64.2,	66.8		
	0925	38°54'	139°08'	3	78.2,	78.3,	79.9	
	1110	39°01'	139°00'	2	63.7,	74.5		
	1922	39°40'	138°12'	1	68.5			

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[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 3.--Albacore troll catch, John R. Manning (cruise 36)(cont'd)

Date 1957	Zone time[1/]	Position		Number of fish	Fork length (cm.)				
		North latitude	West longitude						
6/22	1510	40°23'	137°06'	1	65.7				
	1700	40°34'	136°52'	4	63.0,	66.9,	74.0,	74.2	
6/23	1130	41°33'	135°04'	2	75.8,	76.6			
	1410	41°11'	135°04'	4	75.0,	76.0,	76.2,	77.6	
	1700	40°55'	135°03'	3	66.4,	68.5,	-		
	1750	40°49'	135°03'	1	65.5				
	1820	40°47'	135°03'	1	79.0				
	1830	40°46'	135°03'	4	64.2,	65.5,	67.2,	74.8	
6/25	0830	39°47'	134°50'	4	61.7,	63.9,	66.7,	73.6	
	0905	39°46'	134°49'	4	54.3,	64.3,	65.0,	65.1	
	1930	38°32'	134°33'	2	63.9,	68.1			
6/27	1510	35°51'	133°47'	1	53.4				
6/30	1706	32°58'	129°30'	2	53.4,	53.9			
7/1	0855	33°52'	127°34'	2	63.2,	65.5			
	1315	34°09'	126°57'	1	77.3				
7/2	1120	34°38'	126°01'	1	75.5				
	1215	34°40'	125°54'	1	64.4				
	1615	34°49'	125°32'	2	61.8,	66.8			
	1620	34°49'	125°32'	2	64.6,	70.2			
	1645	34°50'	125°28'	2	63.6,	66.8			
	1750	34°52'	125°22'	2	65.9,	67.2			
7/3	0830	34°56'	126°58'	1	65.7				
	0920	34°56'	127°04'	1	75.3				
7/4	1730	35°05'	131°52'	1	67.3				
7/6	1615	37°11'	129°24'	8	61.5,	61.7,	62.9,	64.7,	65.
					65.4,	66.3,	68.5		
7/7	1625	37°49'	128°28'	2	63.7,	64.2			
7/8	0610	38°45'	127°05'	1	64.5				
	0710	38°49'	127°00'	4	64.1,	64.3,	66.4,	67.9	
	0740	38°51'	126°58'	1	66.2				
	0745	38°51'	126°58'	3	63.7,	65.9,	68.5		
	1032	39°02'	126°43'	1	66.9				
	1100	39°02'	126°42'	2	65.3,	66.2			
7/9	1455	39°59'	126°34'	1	65.3				
	1705	39°59'	126°51'	3	65.5,	74.1,	77.8		
7/10	0920	40°02'	127°07'	3	63.4,	65.7,	65.8		
	1035	40°02'	127°16'	1	66.0				
	1130	40°02'	127°26'	1	78.9				
	1143	40°02'	127°26'	2	63.3,	64.3			
	1604	40°01'	127°54'	1	77.8				
7/11	0600	40°03'	129°38'	1	76.1				
	1906	40°09'	131°31'	1	77.1				
7/12	1400	40°11'	132°52'	1	63.9				
	1650	40°22'	132°33'	1	62.9				
7/14	0700	42°27'	128°57'	1	68.2				
	1225	42°51'	128°23'	1	61.7				
	1615	43°05'	128°07'	3	66.1,	67.7,	69.2		
	1745	43°13'	127°59'	3	66.0,	66.1,	67.1		
	1820	43°14'	127°57'	1	66.9				
	1840	43°16'	127°56'	1	64.2				
	1904	43°17'	127°55'	1	66.1				

[1/] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office fo zone boundaries.

Table 3.--Albacore troll catch, John R. Manning (cruise 36) (cont'd)

ate 957	Zone time[1]	Position		Number of fish	Fork length (cm.)			
		North latitude	West longitude					
/14	1920	43°18'	127°53'	1	63.8			
	2000	43°20'	127°51'	1	64.7			
	2022	43°20'	127°51'	1	64.0			
	2030	43°20'	127°51'	2	64.0,	64.9		
	2035	43°20'	127°51'	1	59.4			
	2040	43°20'	127°51'	1	66.9			
/23	0635	44°32'	126°21'	2	79.6,	81.2		
	0753	44°26'	126°30'	1	67.7			
	0845	44°21'	126°38'	2	63.4,	66.2		
	1235	44°05'	127°02'	4	62.4,	75.9,	77.5,	79.2
	1450	43°54'	127°17'	1	61.6			
	1920	43°44'	127°46'	1	63.8			
	2000	43°42'	127°51'	1	67.9			
/24	0930	43°37'	127°40'	2	64.3,	65.7		
	1330	43°28'	127°09'	1	66.4			
	1505	43°16'	127°11'	1	65.7			
	1530	43°13'	127°12'	1	-			
	1730	43°07'	127°22'	2	60.4,	65.2		
	1930	43°00'	127°35'	1	69.2			
	2012	42°57'	127°40'	3	60.2,	64.2,	65.6	
/25	1545	41°36'	129°56'	1	68.2			
	1947	41°20'	130°17'	1	56.4			
/26	1945	39°52'	131°16'	1	60.9			
/27	1350	38°23'	130°25'	1	53.8			
	1400	38°24'	130°23'	1	55.2			
	1630	38°27'	130°11'	1	57.8			
/28	0610	38°46'	128°44'	1	54.0			
	0640	38°47'	128°40'	3	52.2,	55.4,	58.8	
	0705	38°48'	128°37'	2	54.0,	60.2		
	0745	38°48'	128°39'	1	55.3			
	0835	38°47'	128°39'	2	52.2,	58.8		
	1120	38°48'	128°28'	1	57.2			
	1445	38°49'	128°35'	3	56.9,	57.4,	58.3	
	1545	38°49'	128°40'	1	54.7			
	1600	38°49'	128°40'	1	55.5			
	1610	38°49'	128°44'	2	55.9,	57.0		
/29	0930	38°47'	128°31'	2	57.5,	-		
	1015	38°48'	128°29'	4	59.3,	73.3,	74.1,	84.3
	1800	39°00'	127°31'	3	53.3,	54.8,	55.4	
/2	1030	39°27'	127°30'	2	54.1,	55.3		
/3	0830	38°57'	127°18'	1	63.7			
	1045	38°55'	127°05'	4	74.7,	74.8,	75.1,	83.9
/4	1135	38°55'	125°36'	2	65.0,	66.3		
	1630	38°58'	126°17'	2	65.5,	76.1		
	1730	38°58'	126°26'	1	62.6			
/5	0700	38°22'	125°53'	1	68.8			
	0850	38°17'	125°44'	1	74.9			
/6	0603	37°25'	125°12'	1	65.8			
	0615	37°25'	125°12'	1	67.6			
	0800	37°14'	125°12'	1	60.6			
	1112	37°00'	125°01'	2	62.0,	62.0		
/7	0725	36°41'	124°29'	1	66.2			

[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for one boundaries.

Table 3.--Albacore troll catch, John R. Manning (cruise 36) (cont'd)

Date 1957	Zone time[1]	Position		Number of fish	Fork length (cm.)
		North latitude	West longitude		
8/7	0940	36°35'	124°17'	3	60.7, 66.3, 69.2
	1200	36°29'	124°07'	1	68.1
	1706	36°08'	123°29'	1	59.8
8/8	1645	35°11'	123°23'	3	74.6, 74.9, 80.1
	1900	34°55'	123°22'	2	63.7, 68.0
8/9	0900	34°05'	123°39'	1	64.5
	1030	34°47'	123°45'	1	63.0
	1315	34°50'	124°08'	2	54.2, 57.8
	1320	34°50'	124°10'	1	67.3
	1915	34°46'	124°14'	3	63.8, 66.6, 67.7
8/10	0610	34°19'	125°40'	1	55.8
	0720	34°18'	125°52'	2	52.3, 53.5
	1025	34°17'	126°10'	2	53.1, 54.3
	1800	34°09'	127°08'	1	81.5

[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office fo zone boundaries.

Table 4.--Albacore troll catch, charter vessels

Date 1957	Zone time[1]	Position		Number of fish	Fish length (cm.)
		North latitude	West longitude		
Lancing					(Estimated average)
7/22	0900	45°01'	126°12'	4	76
	1130	45°03'	126°22'	9	68
	1715	45°04'	127°11'	1	68
7/23	0430	45°00'	127°19'	4	66
	1600	44°50'	128°54'	1	66
	1645	44°50'	128°54'	2	66
7/24	0930	45°00'	129°40'	5	69
	1820	45°02'	130°20'	2	69
	1840	45°02'	130°20'	8	69
7/25	1430	45°00'	131°45'	1	69
7/26	0845	44°59'	132°30'	3	69
	0930	45°00'	132°30'	1	69
7/27	1530	44°27'	132°50'	2	69
7/30	1120	44°19'	128°20'	3	69
	1845	44°20'	127°20'	1	69
7/31	0800	44°20'	126°55'	3	69
Gypsy					(Estimated average)
7/22	1845	43°40'	126°37'	5	64
	2040	43°42'	126°57'	1	69
7/23	0655	43°40'	127°09'	2	64
	0950	43°42'	127°33'	5	62
	1405	43°42'	127°55'	3	65

[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office fo zone boundaries.

Table 4.--Albacore troll catch, charter vessels (cont'd)

Date 957	Zone time[1]	Position		Number of fish	Fish length (cm.)
		North latitude	West longitude		
Gypsy - (cont'd)					(Estimated average)
/23	2000	43°42'	127°54'	3	63
/24	0445	43°40'	128°03'	1	64
/25	0500	43°38'	128°52'	2	64
	0700	43°00'	130°05'	1	64
	0950	43°35'	130°26'	6	59
	1445	43°40'	130°54'	4	66
	1725	43°42'	131°08'	5	81
/26	1510	43°41'	132°29'	1	61
/28	0920	42°57'	132°33'	1	76
	1915	43°02'	131°15'	1	66
	1930	43°02'	131°15'	2	69
/29	1825	42°57'	129°35'	1	53
/30	0830	43°00'	129°10'	1	53
	1930	43°00'	127°48'	1	53
/31	0530	42°59'	127°43'	1	64
	1105	42°57'	126°59'	3	66
	1210	42°57'	126°59'	1	58
	1225	42°57'	126°58'	1	66
	1235	42°57'	126°57'	4	69
	1420	42°55'	126°39'	1	66
	1830	42°59'	126°10'	3	69
	2005	42°57'	126°05'	2	66
/1	0705	42°49'	125°50'	1	66
	0825	42°50'	125°47'	2	81
	0900	42°50'	125°11'	1	69
	0920	42°50'	125°38'	1	79
	0940	42°50'	125°37'	1	81
	0950	42°50'	125°36'	2	76
	1005	42°50'	125°34'	5	74
Flicker					(Fork length, cm.)
/22	0800	42°20'	125°42'	1	63
/23	0545	42°20'	127°03'	9	64, 64, 64, 64, 65, 65, 65, 66, 68
	0610	42°20'	127°03'	3	63, 64, 65
	0900	42°20'	127°25'	4	63, 63, 65, 67
	0945	42°20'	127°33'	8	61, 64, 64, 65, 65, 66, 78, 78
	1030	42°20'	127°36'	1	71
	1235	42°20'	127°50'	8	64, 65, 66, 66, 66, 67, 74, 79
	1300	42°20'	127°51'	6	65, 65, 65, 66, 68, 69
/25	1515	42°22'	131°17'	3	54, 54, 54
/26	1700	42°15'	133°00'	1	76
/27	0800	41°44'	133°00'	2	54, 55
	1000	41°40'	132°53'	1	56
	1400	41°40'	132°25'	3	54, 54, 54

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[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 4.--Albacore troll catch, charter vessels (cont'd)

Date 1957	Zone time[1]	Position North latitude	Position West longitude	Number of fish	Fish length (cm.)
Flicker - (cont'd)					(Fork length, cm.)
7/28	0630	41°39'	131°30'	1	64
7/30	0845	41°34'	128°03'	1	64
	1000	41°35'	127°56'	5	54, 54, 54, 54, 66
	1430	41°37'	127°30'	11	55, 55, 55, 59, 60, 61, 61, 62, 65, 66, 67
	1730	41°39'	127°15'	1	57
	1945	41°40'	127°04'	1	66
	2000	41°40'	127°04'	3	55, 56, 57
7/31	0845	41°40'	126°35'	5	64, 65, 65, 66, 68
	0910	41°40'	126°33'	3	52, 64, 65
	1400	41°40'	126°07'	3	63, 64, 66
	1430	41°40'	126°04'	4	64, 65, 66, 66
	1645	41°40'	125°51'	6	63, 64, 64, 65, 65, 65
	1750	41°40'	125°46'	5	64, 66, 67, 69, 75
	1900	41°40'	125°40'	2	64, 66
	2030	41°40'	125°30'	1	65
Lynn Ann					(Estimated average)
7/23	1245	41°00'	127°57'	1	65
7/24	0825	40°55'	128°37'	6	61
	0900	40°55'	128°37'	2	61
	0940	40°56'	128°40'	1	61
	1115	40°59'	128°47'	6	57
	1550	41°00'	129°23'	1	-
	1715	41°01'	129°30'	2	-
7/25	1320	41°00'	130°33'	1	65
	1715	41°01'	130°46'	1	58
	1855	41°01'	130°54'	1	80
7/26	1530	40°57'	131°56'	1	58
7/27	1155	41°00'	133°00'	2	55
7/30	1007	40°24'	128°42'	1	78
	1715	40°24'	127°45'	2	64
7/31	1147	40°22'	126°43'	4	66
Rowland R. Sr.					(Fork length, estimated)
7/22	0805	39°34'	125°00'	1	67
	0930	39°35'	125°10'	4	67, 70, 70, 73
	1200	39°37'	125°35'	9	65, 67, 67, 67, 67, 69, 69, 69, 70
	1310	39°40'	125°40'	3	69, 70, 70
	1422	39°41'	125°47'	1	69
	1450	39°41'	125°49'	2	61, 65
	1620	39°42'	125°59'	6	61, 63, 66, 66, 68, 69
	1645	39°42'	125°00'	1	69
	1720	39°42'	126°04'	3	67, 67, 69
	1820	39°42'	126°08'	5	65, 67, 69, 70, -

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[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office fo zone boundaries.

Table 4.--Albacore troll catch, charter vessels (cont'd)

ate 957	Zone time1/	Position		Number of fish	Fish length (cm.)
		North latitude	West longitude		
owland R. Sr.					(Fork length, estimated)
/23	0542	39°40'	126°25'	2	69, 70
	1145	39°44'	127°00'	6	61, 66, 69, 69, 69, 70
/24	1100	39°34'	128°14'	2	69, 69
/25	1107	39°48'	130°00'	4	56, 56, 57, 57
/26	0600	39°44'	130°45'	1	55
	1508	39°45'	131°44'	1	53
/27	1405	39°15'	132°13'	2	56, 57
/28	1355	38°50'	131°41'	1	57
/30	0845	38°56'	128°56'	1	57
	1425	38°55'	128°15'	2	53, 57
	1455	38°56'	128°12'	2	59, 63
	1630	38°58'	128°00'	23	53, 53, 53, 53, 53, 55, 55, 56, 56, 56, 56, 56, 56, 56, 56, 56, 56, 56, 57, 57, 57, 57, -
/31	0750	39°05'	126°16'	3	61, 61, 62
/1	0530	39°04'	126°18'	1	66
	0645	39°04'	126°17'	3	65, 66, 69
	0715	39°03'	126°08'	4	67, 67, 69, -
	0730	39°03'	126°06'	1	69
	0740	39°02'	126°06'	3	66, 67, 69
llen Cody					(Fork length)
/24	1430	38°18'	126°52'	2	55.6, 55.6
	1635	38°18'	127°08'	2	57.3, 58.7
/25	1100	38°21'	127°42'	2	56.3, 59.4
	1230	38°23'	127°53'	3	61.5, 66.0, 78.6
	1540	38°25'	128°10'	1	61.0
/26	0710	38°21'	128°52'	2	56.0, 57.6
	0835	38°25'	129°03'	4	53.8, 54.5, 54.9, 55.4
	1020	38°25'	129°18'	1	75.7
	1425	38°25'	129°47'	2	53.9, 54.9
/27	0900	38°23'	130°44'	6	53.0, 53.0, 53.9, 54.4, 55.0, 55.5
	1135	38°24'	131°11'	3	53.0, 53.3, 54.0
/28	1340	37°37'	129°42'	6	53.9, 57.0, 57.0, 67.4, 82.7, 86.7
/30	0830	37°42'	127°37'	3	58.7, 59.5, 62.5
	0920	37°42'	127°29'	4	56.0, 57.0, 58.4, 59.0
	0935	37°42'	127°27'	1	56.0
	1035	37°41'	127°20'	2	66.0, 67.0
	1245	37°40'	127°03'	1	57.9
	1320	37°40'	126°55'	1	65.7
/31	1125	37°39'	125°39'	1	72.4
	1415	37°40'	125°22'	5	4 fish estimated - 65 cm., 67.5
	1535	37°42'	125°10'	1	68.4

1/ Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 4.--Albacore troll catch, charter vessels (cont'd)

Date 1957	Zone time[1]	Position		Number of fish	Fish length (cm.)				
		North latitude	West longitude						
Tuna Clipper					(Fork length)				
7/22	1017	37°00'	123°18'	1	78.5				
Luwella					(Fork length)				
7/22	0630	35°39'	122°04'	1	68.0				
	0740	35°41'	122°10'	1	73.0				
	0810	35°45'	122°12'	1	67.5				
	1300	35°44'	122°45'	1	64.5				
	1610	35°43'	122°58'	3	55.5,	59.2,	64.9		
	1700	35°41'	123°04'	1	68.5				
7/23	0600	35°48'	123°22'	1	75.8				
	0630	35°48'	123°27'	1	53.7				
	1000	35°45'	123°37'	4	54.1,	65.9,	66.5,	79.5	
	1100	35°48'	123°46'	1	52.4				
	1200	35°42'	123°54'	1	61.5				
	1230	35°41'	123°55'	1	63.5				
	1630	35°27'	124°20'	1	66.4				
7/25	1145	35°35'	126°22'	1	76.0				
	1300	35°36'	126°30'	1	75.5				
	1655	35°42'	126°42'	1	62.3				
7/26	0640	35°42'	126°58'	1	59.5				
	0720	35°43'	127°03'	1	57.5				
	0745	35°43'	127°05'	2	52.9,	54.5			
	0810	35°45'	127°12'	1	53.5				
	1130	35°45'	127°35'	1	65.5				
	1220	35°45'	127°41'	1	65.5				
	1340	35°44'	128°02'	5	64.0,	64.5,	64.5,	64.5,	65.5
	1430	35°44'	128°06'	2	55.0,	67.0			
	1533	35°45'	128°15'	2	65.5,	67.1			
7/27	0645	35°44'	128°41'	2	64.0,	68.1			
	1000	35°44'	129°10'	1	53.3				
	1035	35°44'	129°14'	1	68.0				
	1100	35°44'	129°17'	2	64.1,	67.4			
	1145	35°45'	129°23'	1	59.1				
	1235	35°44'	129°22'	3	53.5,	64.0,	66.5		
	1400	35°30'	129°20'	1	60.6				
	1425	35°28'	129°28'	3	60.5,	65.3,	66.5		
	1609	35°21'	129°12'	1	65.0				
	1700	35°18'	129°07'	1	68.0				
	1715	35°18'	129°06'	4	64.5,	65.0,	65.5,	66.5	
	1925	35°10'	128°50'	3	51.2,	63.8,	66.5		
7/28	0800	35°11'	128°44'	1	53.2				
7/29	0620	35°04'	127°24'	2	69.4,	70.0			
	1155	35°07'	126°47'	1	66.6				
	1640	35°07'	126°11'	4	64.5,	65.5,	67.5,	67.7	
	1914	35°08'	126°00'	2	65.9,	66.1			
7/30	0730	34°57'	125°30'	3	64.5,	75.0,	75.5		
7/31	0545	34°48'	124°00'	1	63.5				

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[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 4.--Albacore troll catch, charter vessels (cont'd)

Date 1957	Zone time[1]	Position		Number of fish	Fish length (cm.)
		North latitude	West longitude		
Luwella - (cont'd)					(Fork length)
7/31	0740	34°49'	124°05'	1	66.5
	0940	34°54'	123°50'	1	77.0
	1523	34°55'	123°20'	2	65.5, 67.5
	1615	34°56'	123°13'	1	72.4
	1640	34°56'	123°09'	18	59.0, 62.5, 63.5, 63.5, 64.0, 64.5, 65.0, 65.5, 65.5, 65.5, 66.0, 66.5, 66.5, 67.0, 67.4, 68.3, 71.3, 75.5
	1910	34°56'	122°50'	3	64.5, 66.5, 67.5
8/1	0743	34°48'	122°24'	2	64.5, 66.3
	0805	34°49'	122°21'	1	68.5
	0830	34°49'	122°16'	1	64.5
	0900	34°49'	122°13'	1	66.5
	1000	34°49'	122°06'	2	66.0, 68.3
	1100	34°49'	122°00'	1	68.5
	1130	34°49'	121°57'	1	66.5

[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 5.--Troll catch and number of albacore tuna tagged by Honolulu Biological Laboratory and charter vessels

Track number	Vessel	Total catch	Total tagged
-	Hugh M. Smith	112	71
-	John R. Manning	226	104
2	Lynn	23	10
3	Lancing	50	0
4	Gypsy	75	61
5	Flicker	102	100
6	Lynn Ann	32	21
7	Rowland R. Sr.	97	0
8	Allen Cody	53	29
9	Tuna Clipper	1	0
10	Luwella	108	72
Total		879	468

Gill-net Fishing

Eighteen shackles of gill nets with meshes varying from 4 1/2 to 7 1/2 inches, stretched measure, were fished by the Manning. An individual set consisted of a 7 1/2-inch mesh shackle placed at each end of the set and adjoining one of these was a 4 1/2-inch mesh shackle; and eight 5 1/2-inch mesh and seven 6 1/2-inch mesh shackles were alternated in the center of the set. Construction details of the nets are given by Graham and Mann (MS)[3].

Sets were usually made at dusk and retrieved at dawn. One 24-hour station was completed in an area of abundance off Point Arena immediately following an overnight set in which 42 albacore were captured (fig. 2). The 18-shackle set was halved for this operation and five baskets of longline, described below, were attached to an end of each half. Four 6-hour consecutive sets were made, alternating the two halves, between the hours of 1500 on July 30 and 1531 on July 31.

Gill-net catches made during the cruise are given in tables 6 and 7; the lengths of the albacore caught are listed in table 8. A list of the common names of fishes appearing in these tables and other portions of this report is presented in table 9 along with the corresponding scientific names.

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[3] Graham, J. J. and H. J. Mann. MS. Construction and catch selectivity of albacore gill nets in the central North Pacific. Biological Laboratory, Honolulu.

Table 6.--Gill net and attached longline catch, John R. Manning (cruise 36)

Station	Date 1957	Set position		Albacore	Great blue shark	Pomfret	Squid	Miscellaneous	Total	Longline
		North latitude	West longitude							
9	6/18	36°09'	142°52'	0	0	5	2	1 dolphin	8	1 bigeye tuna
11	6/19	36°53'	141°41'	40	1	7	2	1 dolphin	51	
14	6/21	39°42'	138°11'	2	1	3	0	0	6	3 great blue shark
20	6/24	39°57'	134°56'	0	0	6	0	1 scad	7	1 great blue shark
23	6/25	38°32'	134°33'	4	0	3	0	0	7	
24	6/26	36°52'	133°51'	3	1	2	2	0	8	
34	7/1	34°25'	126°24'	2	0	17	0	4 scad	23	3 great blue shark
43	7/5	36°37'	130°12'	7	0	17	1	1 scad 1 dolphin	27	1 great blue shark
46	7/6	37°19'	129°10'	0	1	34	2	7 scad	44	2 great blue shark
50	7/9	39°59'	126°51'	4	37	7	0	5 scad	53	9 great blue shark
66	7/23	43°42'	127°53'	17	23	42	3	1 scad	86	2 great blue shark
81	7/28	38°45'	128°37'	3	10	14	0	0	27	1 great blue shark
83	7/29	39°00'	127°31'	42	45	44	3	14 scad 2 unidentified tuna 1 bonito shark	151	1 great blue shark
83[1/]	7/30	39°01'	127°26'	23	42	34	3	0	102	9 great blue shark
99	8/6	36°45'	124°34'	0	24	10	0	8 scad 1 Risso porpoise	43	9 great blue shark
102	8/9	34°50'	124°10'	3	21	30	1	30 scad 8 unknown	93	10 great blue shark
Total				149[2/]	206	275	19	71 scad 8 unknown 3 dolphin 2 unidentified tuna 1 bonito shark 1 Risso porpoise	736	51 great blue shark 1 bigeye tuna

[1/] 24-hour station.

[2/] An additional unidentified tuna was taken in the gill net and mistaken for albacore. Thus its station could not be determined and the albacore total is given as 149 rather than the 150 to which the column totals.

Table 7.--Twenty-four hour gill-net station 83, 38°58'N., 127°28'W., 7/30-7/31, John R. Manning (cruise 36)

Zone time[1]	Albacore		Great blue shark		Pomfrets		Squid		Attached longline catch-great blue shark		Totals
	alive	dead	alive	dead	alive	dead	alive	dead	alive	dead	
1502-2153	0	6	1	3	7	3	1	0	1	0	22
2003-0358	0	17	12	9	3	16	1	0	1	1	63[2]
0230-0942	0	0	11	3	0	5	0	0	0	0	20[3]
0828-1531	0	0	2	0	0	0	0	0	3	1	6
Total	0	23	26	15	10	24	2	0	5	2	

[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

[2] One squid and 1 great blue shark not recorded as to viableness.

[3] One great blue shark not recorded as to viableness.

Table 8.--Length frequency of albacore captured in gill nets

Fork length (cm.)	Station												Total
	11	14	23	24	34	43	50	66	81	83	24-hour station	102	
50	-	-	-	-	-	-	-	-	-	2	-	-	2
51	-	-	-	-	-	-	-	-	-	10	2	-	12
52	-	-	-	-	-	-	-	-	-	6	4	-	10
53	-	-	-	-	-	-	-	-	-	4	2	-	6
54	-	-	1	-	-	-	-	-	1	8	1	-	11
55	-	-	-	-	-	-	-	-	-	2	5	-	7
56	1	-	-	-	-	-	-	-	2	3	2	-	8
57	-	-	-	-	-	-	-	-	-	2	1	-	3
58	-	-	-	-	-	-	-	-	-	-	-	-	-
59	1	-	-	-	-	-	-	-	-	-	-	-	1
60	4	-	-	-	-	-	-	-	-	-	-	-	4
61	2	-	-	-	-	-	1	-	-	1	-	-	4
62	6	-	-	-	-	-	-	1	-	-	1	-	8
63	4	-	-	-	-	2	-	1	-	-	1	1	9
64	5	1	-	1	-	3	1	3	-	2	-	-	16
65	6	-	-	1	1	1	-	6	-	-	-	1	16
66	6	-	3	-	-	1	-	2	-	-	1	-	13
67	2	-	-	-	1	-	2	1	-	-	1	-	7
68	-	-	-	1	-	-	-	1	-	-	-	1	3
69	-	-	-	-	-	-	-	-	-	1	-	-	1
70	-	-	-	-	-	-	-	-	-	-	-	-	-
71	-	-	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-	-	-
73	-	-	-	-	-	-	-	-	-	-	1	-	1
74	-	1	-	-	-	-	-	1	-	-	-	-	2
75	-	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	-	1	-	-	-	-	1
77	-	-	-	-	-	-	-	-	-	1	-	-	1
78	-	-	-	-	-	-	-	-	-	-	-	-	-
79	-	-	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 9.--Common and scientific names
of fishes mentioned in this report

Common name	Scientific name
Albacore tuna	*Germo alalunga* (Bonnaterre)
Bigeye tuna	*Parathunnus sibi* (Temminck and Schlegel)
Bonito shark	*Isurus glaucus* (Müller and Henle)
Dolphin	*Coryphaena hippurus* (Linnaeus)
Flying fish	Exocoetidae
Great blue shark	*Prionace glauca* (Linnaeus)
Lantern fish	Myctophidae
Pomfret	*Brama raii* (Block)
Saury	*Cololabis saira* (Brevoort)
Scad	*Trachurus symmetricus* (Ayres)
Skipjack tuna	*Katsuwonus pelamis* (Linnaeus)
Sunfish	*Mola mola* (Linnaeus)

Longline Fishing

Five baskets of longline were fished with ach set of gill nets by attaching them to an end f the set. The longline was similar to that sed previously to fish albacore in this area Mann 1955). The basic unit or basket consistd of 210 fathoms of mainline to which floats vere attached at either end. Three-fathom roppers with 1 1/2-fathom leaders were susended from the mainline at 15-fathom interals so that there were 13 hooks to a basket. 'his basic gear was modified to fish at varying epths by changing the depth of the floatline nd placing an extra buoy at the center of the asket (omitting the hook at that position). The ive baskets were arranged in the following rder, starting at the attached end: Two had buoys (one in the center) and no floatlines; wo had 2 buoys and no floatlines; and the fifth ad 2 buoys and 2-fathom floatlines. A soundng tube (Graham 1957) was placed on each asket of gear; and these showed that during he cruise the minimum fishing depth was about 5 feet and the maximum about 430 feet. No lbacore were taken on this gear (tables 6 and).

A single albacore (68.6 cm. in fork length) vas captured on a special set of longline which eplaced a scheduled gill-net station cancelled ecause of a winch breakdown. Five baskets, ach equipped with 3 buoys (one in the center) nd no floatlines, were fished. This special et was made immediately following a catch of ish on trolling lines and extended from 1345 hrough 1800 hours (fig. 2). The hooks were aited with small herring (< 6 inches), in conrast to the five baskets attached to gill nets on vhich large herring (> 6 inches) were used.

STOMACH ANALYSES

One hundred and ninety-five albacore stomachs were examined in the field and 43 stomachs, believed to contain food, were preserved for laboratory analysis. In the field study, food items were divided into the following major groups: Squid, saury, other fish, shrimp-like plankton, and copepod and amphipod-like plankton. Food items of the first hree groups were rated as to size by considerng total lengths less than 5 inches as small, 5 hrough 10 inches as medium, and greater than 10 inches as large. The displacement volume (≥5 ml.) of the contents of each stomach was etermined and any unidentifiable remains noted. The data obtained with both types of gear, troll and gill net, are presented in table 10.

HOLDING EXPERIMENTS

The rectangular port brine tank, 8 1/2 feet deep and 6 1/2 feet wide fore and aft, of the John R. Manning was used to hold troll-caught albacore which were landed alive and in good condition. Water entering the tank flowed diagonally across the upper portion of the tank and then returned along its sides and bottom. Water was removed from the bottom diagonally across from the inflow. The volume of flow was such that the contents of the 2,150-gallon tank were replaced approximately every 35 minutes. Fourteen albacore, ranging from 54 cm. to 68 cm. in fork length, were held in the tank for periods varying from a few minutes to 14 hours (table 11).

NIGHT-LIGHT OBSERVATIONS

Observations of organisms under lights were made from the Smith (table 12), the Manning (table 13), and two charter vessels (table 14) while they were drifting at night. The Smith made her observations under deck lights, which remained on all night, by estimating every 2 hours the number and size of sauries present. The Manning turned on the deck lights for 1 hour during darkness and estimated the number, and usually the size, of sauries and squids which were attracted. The charter vessel Flicker made observations between 2130 and 2200 hours each night using a single sealed-beam light. Twenty or fewer sauries, when seen at one instant during the period of observation, were classed as few, 21 to 50 as moderate, and 51 or more as abundant. The Rowland R. Sr. made her observations at 2200 and the amount of bait or forage and the amount of luminescence were recorded in relative terms.

SIGHTINGS OF FISH, BIRDS, AQUATIC MAMMALS

The wheel watches of the Smith and Manning maintained logs of fish, birds, and aquatic mammals sighted during the daylight hours. These observations are tabulated in tables 15 and 16. The charter vessels also maintained a rough log of such sightings which are tabulated in table 17.

Table 10.--Field examination of albacore stomach contents, John R. Manning (cruise 36)
Gill net-caught fish, (S = < 5 inches, M = 5-10 inches, L = > 10 inches)

Date 1957	Station	Squid			Saury			Other fish			Plankton		Unidentifiable remains	Volume ml.
		S	M	L	S	M	L	S	M	L	Shrimp-like	Copepod and amphipod-like		
6/20	11	-	-	-	-	2	-	-	-	-	-	-	x	40
6/20	11	2	-	-	-	-	-	3	-	-	1	-	x	10
6/20	11	-	-	-	-	-	-	1	1	-	1	-	x	25
6/20	11	1	-	-	-	-	-	1	-	-	3	-	x	10
6/20	11	-	-	-	-	-	3	-	-	-	-	-	-	110
6/20	11	-	-	-	-	2	-	-	-	-	-	-	-	60
6/20	11	3	1	-	-	-	-	-	-	-	7	-	-	10
6/20	11	-	1	-	-	-	-	-	-	-	1	-	x	7
6/20	11	3	-	-	1	-	-	7	-	-	-	-	x	20
6/20	11		26 albacore examined, all < 5 ml.											< 5
6/22	14		2 albacore examined, both < 5 ml.											< 5
6/26	23		4 albacore completely empty											< 5
7/2	34	-	1	-	-	-	-	-	1	-	-	-	x	8
7/2	34	-	-	-	-	-	-	-	-	-	-	-	x	< 5
7/6	43	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/6	43	2	-	-	-	-	-	-	1	-	-	-	x	13
7/6	43	6	2	-	-	1	-	1	-	-	-	-	x	20
7/6	43	-	-	1	-	-	-	-	-	-	-	-	x	9
7/6	43	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/6	43	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/10	50	-	1	-	-	-	-	-	-	-	-	-	-	6
7/10	50		3 albacore examined, all < 5 ml.											< 5
7/24	66	-	3	-	-	-	-	-	-	-	-	-	-	10
7/24	66		16 albacore examined, all < 5 ml.											< 5
7/29	81		3 albacore examined, all < 5 ml.											< 5
7/30	83		37 albacore examined, all < 5 ml.											< 5
8/8	102		3 albacore examined, all < 5 ml.											< 5

Table 10.--Field examination of albacore stomach contents, John R. Manning (cruise 36) (cont'd)
Troll-caught fish, (S = < 5 inches, M = 5-10 inches, L = > 10 inches)

Date 1957	Zone time of capture	Squid			Saury			Other fish			Plankton		Unidentifiable remains	Volume ml.
		S	M	L	S	M	L	S	M	L	Shrimp-like	Copepod and amphipod-like		
6/19	1615	9	-	-	-	-	-	4	-	-	2	-	x	35
6/19	1635	-	-	-	-	-	-	-	-	-	-	-	-	< 5
6/20	1930-2005[1]	-	-	-	-	-	-	1	-	-	-	3	x	10
6/20	"	-	-	-	-	-	-	-	-	-	-	-	x	< 5
6/21	0655-1922	-	-	-	-	-	1	1	-	-	-	-	x	45
6/21	"	-	-	-	3	-	-	14	-	-	-	-	-	15
6/21	"	-	-	-	-	-	-	-	-	-	-	-	-	< 5
6/22	1700	-	-	-	2	-	-	4	-	-	-	-	x	20
6/22	"	-	-	-	2	-	-	2	-	-	1	-	x	15
6/23	1130-1830	-	-	-	-	-	-	2	1	-	-	-	x	10
6/23	"	-	-	-	-	1	-	3	-	-	-	-	x	20
6/23	"	-	-	-	6	-	-	-	-	-	-	-	x	35
6/23	"	-	-	-	-	3	1	-	-	-	-	-	-	40
6/23	"	-	-	-	3	-	-	-	-	-	-	-	-	10
6/25	0830-1930	4	-	-	-	-	-	-	-	-	1	-	x	10
6/25	"	-	-	-	4	-	-	-	-	-	-	-	x	10
6/25	"	-	3	-	2	-	-	-	-	-	-	-	x	25
6/25	"	-	-	-	9	-	-	-	-	-	-	-	-	15
6/25	"	-	-	-	-	-	1	-	-	-	-	-	x	20
6/25	"	-	-	-	-	-	-	-	-	-	-	-	x	< 5
6/25	"	-	-	-	2	-	-	-	-	-	-	-	x	6
6/27	1510	-	-	-	-	-	-	-	-	-	-	-	-	< 5
6/30	1705	1	-	-	-	-	-	2	-	-	-	1	-	5
7/1	0855-1315	-	1	-	-	-	-	-	-	-	1	-	-	15
7/1	"	-	1	-	-	-	-	-	-	-	-	-	x	8
7/2	1120	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/2	1620	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/2	1645	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/2	1750	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/2	"	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/2	1620	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/3	0920	-	-	-	-	-	-	-	1	-	-	-	-	7
7/6	1615	-	-	-	11	-	-	-	-	-	-	-	-	20
7/6	"	-	-	-	13	-	2	-	-	-	-	-	-	80
7/6	"	-	-	-	-	-	-	-	-	-	-	-	-	< 5

[1] Exact time of capture not determined.

Table 10.--Field examination of albacore stomach contents, John R. Manning (cruise 36) (cont'd)
Troll-caught fish (S = < 5 inches, M = 5-10 inches, L = >10 inches) (cont'd)

Date 1957	Zone time of capture	Squid			Saury			Other fish			Plankton		Unidentifiable remains	Volume ml.
		S	M	L	S	M	L	S	M	L	Shrimp-like	Copepod and amphipod-like		
7/7	1625	-	-	-	-	-	1	-	-	-	-	-	-	25
7/8	0610	-	-	-	3	-	-	-	-	-	-	-	-	6
7/8	0710	-	-	-	6	-	-	-	-	-	-	-	-	11
7/8	"	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/8	0745	-	-	-	4	5	-	-	-	-	-	-	-	30
7/8	"	-	-	-	7	-	-	-	-	-	-	-	-	12
7/8	1100	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/8	"	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/10	0920	-	-	-	-	-	1	-	-	-	-	-	x	38
7/10	"	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/10	1035	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/10	1140	-	-	-	-	2	1	-	-	-	-	-	x	15
7/10	1142	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/12	1650	5	-	-	-	-	-	1	-	-	-	-	-	10
7/14	0700	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/14	1615	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/14	1745	-	-	-	-	-	1	-	-	-	-	-	x	10
7/14	1820	-	-	-	-	7	-	-	-	-	-	-	-	50
7/14	1904	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/14	2022	-	-	-	3	-	-	-	-	-	-	-	-	7
7/14	2035	3	-	1	-	3	-	-	-	-	-	-	x	40
7/23	1235	-	1	-	-	-	-	-	-	-	-	-	x	5
7/23	0635	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/23	0753	-	-	-	1	-	-	-	-	-	-	-	x	< 5
7/23	0635	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/23	0845	-	-	-	-	-	-	-	-	-	-	-	x	20
7/23	1235	-	-	-	-	-	-	-	-	-	-	-	x	15
7/23	1450	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/23	1920	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/23	2000	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/24	1930	-	-	-	-	2	-	-	-	-	-	-	-	8
7/25	1545	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/25	1950	-	1	-	-	-	-	-	-	-	-	-	-	6
7/28	0610	-	-	-	-	-	-	4	-	-	-	-	-	15
7/28	0640	3	-	-	-	-	-	6	-	-	-	-	x	15
7/28	1545	-	-	-	-	-	-	-	-	-	-	-	-	< 5
7/28	0705	-	-	-	-	-	-	-	-	-	-	-	-	< 5

Table 10.--Field examination of albacore stomach contents, John R. Manning (cruise 36) (cont'd)
Troll-caught fish (S = < 5 inches, M = 5-10 inches, L = > 10 inches) (cont'd)

Date 1957	Zone time of capture	Squid			Saury			Other fish			Plankton		Unidentifiable remains	Volume ml.
		S	M	L	S	M	L	S	M	L	Shrimp-like	Copepod and amphipod-like		
7/29	0930	-	-	-	-	-	-	-	-	-	-	-	-	< 5
8/3	0830	-	-	-	-	-	-	-	8	-	-	-	-	30
8/3	1045	-	-	-	1	-	2	-	-	-	-	-	-	110
8/3	"	-	-	-	-	1	-	-	-	-	-	-	-	30
8/3	"	-	-	-	2	-	3	-	-	-	-	-	-	273
8/4	1135	-	-	-	-	-	-	-	-	-	-	-	-	< 5
8/4	1630	-	-	-	-	-	-	-	2	-	-	-	-	12
8/5	0850	-	-	-	-	-	-	-	-	-	-	-	-	< 5
8/6	0600	-	-	-	-	-	-	-	-	-	-	-	-	< 5
8/6	1112	-	-	-	-	-	-	-	1	-	-	-	x	8
8/10	0610	-	-	-	-	-	-	-	-	-	-	-	-	< 5

Table 11.--Albacore holding experiments, John R. Manning (cruise 36)

Date 1957	Length of troll line (feet)	Time placed in tank	Time of death	Survival time hours	Remarks
7/23	150	2000	2030	1/2	
7/23	150	1920	2030	1-1/4	
7/24	135	0930	0945	1/4	Lampblack applied to the eyes.
7/24	65	0930	0945	1/4	" " " " "
7/24	90	1445	1500	1/4	
7/24	90	1530	2000	4-1/2	Jumped out of tank.
7/25	65	1615	0300-0700, 7/26[1]	10-3/4 - 14-3/4	Rough weather
7/26	150	1945	1950	< 1/4	
7/27	150	1630	2130	5	Artificial respiration with hose
7/28	150	0610	0815	1/2	No separate tally kept on individual fish. No line assigned for individual fish. Survival time figured from 0745.
7/28	80	0640	1045	3	
7/28	90	0640	1045	3	
7/28	65	0640	1500	7-1/4	
7/28	65	0745	2200	14-1/4	

[1] Exact time of death not determined.

Table 12.--Night-light observations of sauries by the *Hugh M. Smith* (cruise 40)

Date 1957	Zone time[1]	North latitude	West longitude	Numbers estimated	Estimated length in inches
7/17	2030	45°54'	125°27'	1,000	6
7/23	0020	47°02'	127°10'	0	-
	0200	47°02'	127°08'	0	-
	2200	47°00'	129°08'	1,000	4-8
7/24	0100	47°00'	129°08'	1,000	1-14
	0430	47°02'	129°09'	1,000	1-14
7/25	0200	46°46'	130°46'	0	-
7/29	0200	45°12'	126°46'	0	-
	0400	45°10'	126°44'	1,000	3-4
7/30	0230	43°49'	124°43'	1,000	3-4
7/31	0000	42°55'	127°01'	10	2
	0200	42°53'	127°02'	1,000	3-4
	0400	42°51'	127°02'	0	-
8/1	0200	42°13'	129°08'	0	-
	0500	42°10'	129°09'	10	3-4
8/2	0200	41°33'	130°41'	50	1-3
	0430	41°31'	130°44'	0	-
	0445	41°31'	130°44'	1	14
8/3	0200	41°17'	128°19'	0	-
8/4	0000	40°58'	126°00'	10	3
	0200	40°52'	125°57'	6	4-6
	2355	40°25'	126°16'	0	-
8/5	0200	40°25'	126°19'	0	-
	0435	40°23'	126°21'	0	-
8/7	0200	39°30'	131°00'	0	-
	2355	39°07'	128°40'	0	-
8/8	0200	39°06'	128°40'	0	-
8/9	0000	39°03'	127°00'	0	-
	0200	39°05'	126°55'	0	-
8/10	0000	38°56'	124°24'	0	-
	0200	38°54'	124°22'	1	5
8/13	0000	37°09'	128°35'	0	-
	0200	37°06'	128°32'	0	-
8/14	0000	36°51'	126°33'	0	-
	0200	36°49'	126°31'	0	-
	0430	36°46'	126°28'	0	-

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[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 13.--Night-light observations by the John R. Manning (cruise 36)

Date 1957	Position		Present not persistent	Numbers persistent under the lights			Approximate size	
	North latitude	West longitude		1-5	6-10	11-30	Sauries	Squids
6/18	36°10'	142°52'	-	Myctophids	-	-	-	-
				Squids	-	-	-	> 12 inches
6/19	36°53'	141°41'	Myctophids	Sauries	-	-	< 4 inches	-
				Squids	-	-	-	> 12 inches
6/21	39°43'	138°09'	Sauries	-	-	-	-	-
			Squids	-	-	-	-	> 12 inches
6/24	39°57'	134°56'	-	Sauries	-	-	< 4 inches	-
6/25	38°30'	134°35'	Myctophids	Sauries	-	-	-	-
			Squids	-	-	-	-	> 12 inches
6/26	36°49'	133°51'	Sauries	-	-	-	< 4 inches	-
			Myctophids	-	-	-	-	-
7/1	34°25'	126°26'	Sauries	-	-	-	< 4 inches	-
			Squids	-	-	-	-	> 12 inches
7/5	36°37'	130°12'	Sauries	-	-	-	4-8 inches	-
7/6	37°19'	129°10'	Sauries	-	-	-	-	-
7/9	39°59'	126°51'	-	-	-	-	-	-
7/23	43°42'	127°53'	-	-	Sauries	-	-	-
7/28	38°45'	128°37'	Sauries	-	-	-	-	-
			Myctophids	-	-	-	-	-
7/29	39°00'	127°31'	Squids	-	-	Sauries	-	> 12 inches
			Myctophids	-	-	-	-	-
8/2	39°06'	127°31'	-	-	-	-	-	-
8/7	36°08'	123°29'	Sauries	-	-	-	-	-
			Myctophids	-	-	-	-	-
8/8	34°48'	123°22'	Sauries	-	-	-	-	-
			Squids	-	-	-	-	-

Table 14.--Night-light observations by the charter vessels

Date 1957	North latitude	West longitude	Sauries	Myctophids	Miscellaneous
Flicker					
7/22	42°20'	127°00'	Abundant	0	Ctenophora Pteropods
7/23	42°20'	128°45'	Abundant	0	Amphipods Salpa chains Pteropods
7/24	42°20'	130°45'	Abundant	20	2 salpa types 1 velella 1 invertebrate ?
7/26	42°00'	133°00'	Few	0	Weather rough
7/27	41°40'	131°40'	Few	1	-
7/28	41°30'	129°55'	Few	0	Salpa chains
7/29	41°32'	128°25'	Moderate	2	Salpa chains
7/30	41°40'	127°00'	Abundant	9	1 jellyfish
Roland R. Sr.			Luminescence		Bait
7/22	39°45'	124°40'	Very little		None
7/23	39°43'	127°50'	Very little		None
7/24	39°44'	129°20'	Very little		None
7/25	39°48'	131°00'	None		None
7/26	39°47'	132°20'	None		None
7/27	39°00'	131°48'	None		None
7/28	38°56'	130°51'	None		None
7/29	39°05'	129°13'	None		None
7/30	39°03'	127°41'	Small amount		None
7/31	39°05'	129°44'	None		None

Table 15.--Fish, bird flocks, and aquatic mammals sighted

Date 1957	Zone time[1]	Noon position		Fish	Bird flocks	Aquatic mammals
		North latitude	West longitude			
7/4	1703	26°39'	152°42'	25 flying fish	-	-
	1730			-	-	1 whale
7/10	1229	42°20'	140°09'	1 sunfish	-	-
7/11	0700	44°39'	137°52'	-	Petrels (< 10)	-
	0805 through 1440			-	Many small unidentified birds	-
7/12	1143	44°02'	136°29'	-	-	5 porpoise
	1603			-	-	30 porpoise
7/16	1639	44°51'	130°01'	-	-	1 whale
7/18	0935	46°16'	124°16'	Medium-size, unidentified school	Petrels (11-50)	-
7/22	0911	46°59'	126°08'	-	-	2 porpoise
	1645			-	-	1 whale
	1655			1 great blue shark	-	-
7/23	0630	47°00'	127°47'	1 great blue shark	-	-
	1400			Albacore tuna school	-	-
7/24	1440	46°45'	130°14'	1 shark	-	-
	1647			Albacore tuna school	-	-
7/25	1115	46°46'	131°57'	-	-	1 seal
	1709			-	-	1 whale
7/26	1445	46°37'	133°04'	-	Snipes (?) (> 50)	-
	2010			-	-	1 seal
7/29	1535	44°25'	125°59'	-	-	1 whale
	1540			1 sunfish	-	-
	1550			-	-	4 whales
	1607			1 sunfish	-	-
	1730			Small-size school of anchovies (dead and floating)	-	-
	1835			1 sunfish	-	-
	1840			-	-	25 whales
	1945			-	-	6 porpoise
7/30	0635	43°22'	129°59'	-	-	3 whales
	0709			-	-	4 whales
	0810			1 great blue shark	-	-
	0853			1 great blue shark 1 manta	-	-

[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 15.--Fish, bird flocks, and aquatic mammals sighted from the Hugh M. Smith (cruise 40) (cont'd)

Date 1957	Zone time[1]	Noon position		Fish	Bird flocks	Aquatic mammals
		North latitude	West longitude			
7/30	0910	43°22'	129°59'	-	-	Porpoise school
	0920			-	-	12 porpoise
	1720			-	-	35 porpoise
	1925			-	-	2 whales
8/1	0810	41°51'	131°04'	1 sunfish	-	-
	1925			1 sunfish	-	-
8/3	1720	41°05'	127°00'	1 great blue shark	-	-
	1735			-	-	2 whales
8/4	0635	40°44'	125°08'	1 sunfish	-	-
	0715			-	-	Porpoise school
	1128			-	-	6 porpoise
	1205			-	-	12 porpoise
	1247			-	-	1 porpoise
8/9	0835	39°10'	125°41'	1 great blue shark	-	-
	0845			-	Snipes (?) (11-50)	-
	0916			-	Snipes (?) (11-50)	-
8/11	0652	38°04'	127°41'	Large-size school of bait fish	-	-
8/13	1015	37°01'	127°38'	-	Snipes (?) (11-50)	-
	1638			-	-	1 whale
8/14	0655	36°58'	125°32'	1 great blue shark	-	-
8/26	1530	San Francisco		-	-	1 killer whale
8/27	0759	37°19'	123°07'	-	-	3 sperm whales
8/29	0700	32°14'	130°17'	-	-	2 sperm whales
	1125			-	-	6 porpoise
	1305			-	-	15 porpoise
8/30	1242	30°48'	134°09'	-	-	Large school of porpoise
	1642			-	-	2 whales
8/31	1617	29°16'	138°11'	Medium-size school of skipjack tuna	-	-
9/3	1635	24°43'	145°28'	-	-	1 sperm whale
9/4	0530	23°08'	153°12'	20 flying fish	-	-
	0600			50 flying fish	-	-
	1545			Small-size school of skipjack tuna	(11-50) petrels or shearwaters	-

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[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries

Table 16.--Fish, bird flocks, and aquatic mammals sighted from the John R. Manning (cruise 36)

Date 1957	Zone time[1]	Noon position		Fish	Bird flocks	Aquatic mammals
		North latitude	West longitude			
6/12	0730	22°33'	156°45'	-	Terns (< 10)	-
	1215			1 flying fish	-	-
6/13	1250	24°42'	154°21'	1 flying fish	-	-
	1305			100 flying fish	-	-
6/14	1210	26°48'	152°14'	3 flying fish	-	-
6/17	0730	33°35'	145°19'	Medium-size school of large unidentified fish	-	-
	0845			-	-	1 sperm whale
6/20	1650	37°09'	141°15'	Small-size school of flying fish	-	-
6/21	0845	39°18'	138°39'	Large-size school of albacore tuna	-	-
	1110			Large-size school of albacore tuna, 15-20 pound fish	-	-
6/22	0835	40°09'	137°27'	-	Petrels (< 10)	-
	0930			-	Petrels (< 10)	-
	1005			-	Petrels (< 10)	-
6/23	1240	41°29'	135°05'	-	Petrels (< 10)	-
	1420			-	-	1 whale
7/1	1320	34°02'	127°12'	-	-	1 whale
	1625			1 flying fish	-	-
7/7	1310	37°32'	128°53'	-	Shearwaters (< 10)	-
7/12	1341	40°03'	133°03'	-	-	3 porpoise
7/13	1705	41°42'	130°22'	1 sunfish	-	-
7/14	1750	42°49'	128°26'	Albacore tuna school	Shearwaters (< 10)	-
7/15	1035	44°32'	126°28'	-	-	1 whale
	1645			1 shark	-	-
7/26	1645	40°47'	131°20'	1 shark	-	-
7/29	1230	38°56'	127°05'	-	-	8 whales
7/31	1205	38°59'	127°28'	2 sunfish	-	6 killer whales
8/3	1645	38°48'	127°09'	Large school of saury	-	-
	1740			-	-	1 whale
8/5	0930	38°05'	125°25'	-	-	1 humpback whale
	0935			1 sunfish	-	-
				1 shark		

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[1] Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 16.--Fish, bird flocks, and aquatic mammals sighted from the John R. Manning (cruise 36) (cont'd)

Date 1957	Zone time1/	Noon position		Fish	Bird flocks	Aquatic mammals
		North latitude	West longitude			
8/5	1200	38°05'	125°25'	School of bait	-	6 porpoise
	1242			Large school of bait	-	-
	1335			2 great blue shark	-	1 porpoise
	1419			-	-	4 porpoise
	1425			1 great blue shark	-	-
8/8	1305	35°44'	123°24'	-	-	1 seal
	1423			-	-	10 porpoise
8/9	0815	34°48'	123°54'	-	-	2 porpoise
8/10	1740	34°16'	126°21'	1 flying fish	-	-
8/15	0720	28°28'	142°56'	2 large schools of flying squid	-	-
	0800			Flying squid	-	-
	0820			Flying squid	-	-
	0905			Flying squid	-	-
	0935			Flying squid	-	-

1/ Consult the Standard Time Chart of the World (HO 5192) of the U. S. Hydrographic Office for zone boundaries.

Table 17.--Fish, birds, and aquatic mammals sighted from charter vessels

ate 957	Noon position		Daily summary of observations
	North latitude	West longitude	
			Lancing
/22	45°03'	126°22'	A few birds
/23	44°06'	128°18'	3 albatross
/24	43°05'	129°05'	2 groups of unidentified fish or whales, 4 to 8 in each group
/31	44°20'	126°13'	A few small birds, 1 whale
			Gypsy
/27	43°28'	133°25'	Some feed and porpoise
/29	42°56'	130°20'	2 albatross
/30	43°02'	128°37'	2 albatross
/31	42°56'	126°51'	Albatross
/1	42°50'	125°36'	Several fish sighted
			Flicker
/26	42°22'	132°34'	20 small sandpiper-like birds
/27	41°40'	132°39'	2 small whales, 10 killer whales
/28	41°36'	130°53'	6-foot great blue shark, bait breaking the surface
/29	41°30'	129°13'	Medium-size sunfish
/30	41°36'	127°45'	Small brownish to black whale
/31	41°40'	126°18'	44 porpoise, 1 large whale
			Lynn Ann
/22	41°00'	125°43'	1 albatross, 3 petrels, 2 whales, 3 unidentified birds
/25	41°00'	130°17'	A few albatross and petrels
/26	40°55'	131°26'	1 albatross, 2 petrels
/27	41°00'	133°00'	2 albatross, 1 petrel
/28	40°20'	131°54'	8 petrels, 1 shearwater, 2 albatross
/29	40°20'	130°19'	3 killer whales, 1 petrel
/30	41°26'	128°27'	12 petrels, 6 albatross, 4 unidentified birds, at one instance during the day 20 birds were sitting on the water
/31	40°22'	126°42'	5 porpoise, 4 great blue sharks, 9 petrels, 1 shearwater, 35 unidentified birds
			Rowland R. Sr.
/22	39°37'	125°35'	15 porpoise
/25	40°00'	130°10'	1 petrel
/26	39°43'	131°24'	Sauries jumping, 9 petrels, 2 albatross
/27	39°20'	132°10'	7 petrels, 1 albatross
/28	38°45'	131°57'	6 petrels, 1 albatross
/29	39°00'	130°05'	7 albatross, 2 petrels
/30	38°52'	128°25'	Small school of bait, 18 to 20 fish, 3 inches in length; sauries, 3 inches in length, 1 albatross, 1 petrel
/31	38°55'	127°22'	1 petrel, 1 shearwater
			Allen Cody
/24	38°18'	126°32'	Whales and sharks
/31	37°35'	126°16'	Large school of whales, some small fish

Table 17.--Fish, birds, and aquatic mammals sighted from charter vessels (cont'd)

Date 1957	Noon position		Daily summary of observations
	North latitude	West longitude	
			Luwella
7/23	35°45'	123°37'	1 albatross
7/24	35°32'	124°39'	1 albatross
7/25	35°35'	125°14'	1 albatross, 1 petrel
7/27	35°45'	129°24'	2 albatross, 2 petrels
7/28	35°02'	128°25'	2 albatross, 1 shearwater
7/29	35°07'	126°47'	3 albatross, 1 petrel, 2 unidentified birds, 1 flying fish
7/30	34°52'	125°00'	2 albatross, 2 petrels, 1 tropic bird
7/31	34°55'	123°20'	Jumping sauries, 1 shark, 1 petrel, 1 unidentified bird
8/1	34°49'	121°48'	10 porpoise, 20 to 30 sunfish, 2 sharks, 2 petrels, 8 to 10 unidentified birds

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CONSTRUCTION AND CATCH SELECTIVITY OF ALBACORE GILL NETS USED IN THE CENTRAL NORTH PACIFIC

By Joseph J. Graham* and Herbert J. Mann**

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Type of Gear Used 2
Selectivity of Mesh Size 3
Summary 6
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INTRODUCTION

A comprehensive study of the resources of the albacore tuna, *Germo alalunga* (Bonnaterre), north and northeast of the Hawaiian Island chain under Public Laws 329 and 466 (the latter known as the Saltonstall-Kennedy Act) has been made by the Pacific Oceanic Fisheries Investigations (POFI) of the U. S. Bureau of Commercial Fisheries. One of the important objectives of the study has been to uncover concentrations of albacore of commercial magnitude. It is likely such a concentration was brought to light by cruises in 1955 and 1956 (fig. 1).

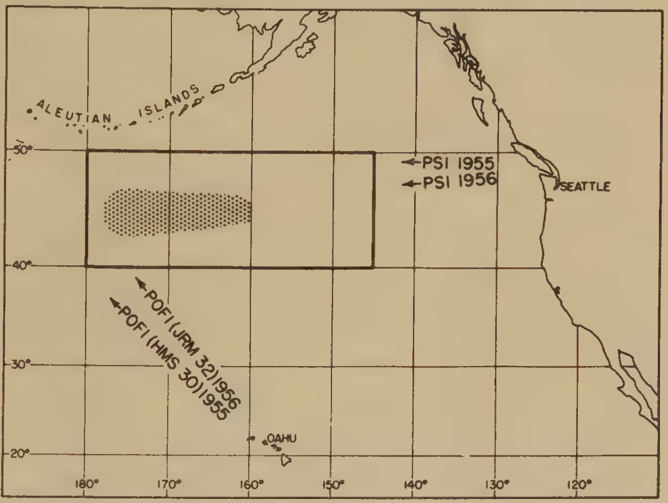

Fig. 1 - Outline of the general region surveyed during 1955 and 1956 by Pacific Oceanic Fishery Investigations and Pacific Salmon Investigations. The area of albacore concentrations is shaded.

The principal gear that made this discovery possible was the gill net, and events leading up to its use by POFI in the North Pacific began in 1955. During the summer of that year, the POFI research vessel *Hugh M. Smith* (cruise 30) surveyed the central North Pacific (fig. 1) with vessels of Pacific Salmon Investigations (PSI) of the U. S. Fish and Wildlife Service (Powell and Peterson 1957). The *Hugh M. Smith* conducted hydrographic stations while determining the distribution and abundance of albacore tuna with trolling gear. The PSI vessels attempted to delineate the distribution of high-seas salmon by gill-netting at night. Catches of albacore on the trolling gear were mediocre. However, albacore were taken in the salmon gill nets at the more southern stations (48° N.-45° N.) of the PSI vessels. A few of those catches were impressive, particularly since most of the fish were not gilled, but entangled in the small-meshed salmon nets[1]. The following year, during the same period and in the same area, the POFI research vessel *John R. Manning* made a fishing survey (cruise 32) in cooperation with PSI. Gill-netting was extended farther south (43° N.) by POFI where a greater abundance of albacore was anticipated and larger mesh sizes more suitable for albacore were used. Again albacore were found concentrated in about the same area, and were taken in that vessel's gill nets in near-commercial quantities.

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* Fishery Research Biologist
** Fishery Methods & Equipment Specialist
} Pacific Oceanic Fishery Investigations, U. S. Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii.

[1] Personal communication to Director, POFI, Honolulu, T. H., from Chief, Pacific Salmon Investigations, Seattle, Wash., September 20, 1955.

TYPE OF GEAR USED

The gill nets fished by POFI were of a design currently in use in the salmon fishery of the northwest coast of America. In addition, trammel nets designed specifically by POFI gear specialists for albacore fishing were utilized. The construction details of both types of nets are shown in figure 2. A unit of gear, the shackle, measured 50 fathoms in length and about 4 fathoms in depth regardless of mesh size. A set at a gill-net station was composed of 12 shackles of gill net and 2 shackles of trammel net joined together. The mesh sizes of the gill-net shackles were $4\frac{1}{2}$ inches, $5\frac{1}{2}$ inches, $6\frac{1}{2}$ inches, and $7\frac{1}{2}$ inches (stretched mesh). Construction details of the gill-net and trammel-net shackles are summarized in tables 1 and 2, respectively. Nets were hung in a conventional manner with the webbing 50 percent

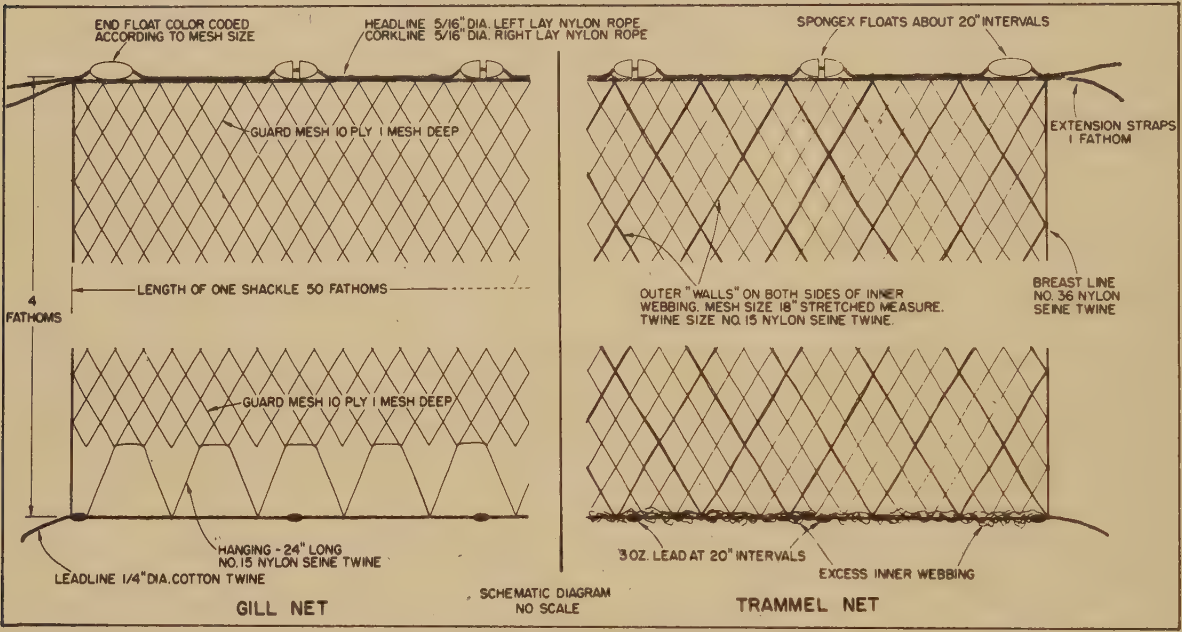
END FLOAT COLOR CODED ACCORDING TO MESH SIZE
HEADLINE 5/16" DIA. LEFT LAY NYLON ROPE
CORKLINE 5/16" DIA. RIGHT LAY NYLON ROPE
SPONGEX FLOATS ABOUT 20" INTERVALS
GUARD MESH 10 PLY 1 MESH DEEP
EXTENSION STRAPS 1 FATHOM
4 FATHOMS
LENGTH OF ONE SHACKLE 50 FATHOMS
OUTER "WALLS" ON BOTH SIDES OF INNER WEBBING. MESH SIZE 18" STRETCHED MEASURE. TWINE SIZE NO. 15 NYLON SEINE TWINE.
BREAST LINE NO. 36 NYLON SEINE TWINE
GUARD MESH 10 PLY 1 MESH DEEP
HANGING - 24" LONG NO. 15 NYLON SEINE TWINE
LEADLINE 1/4" DIA. COTTON TWINE
3 OZ. LEAD AT 20" INTERVALS
EXCESS INNER WEBBING
SCHEMATIC DIAGRAM NO SCALE
GILL NET
TRAMMEL NET

Fig. 2 - Construction details of POFI albacore nets.

Table 1 - Gill-Net Specifications

Mesh Size (Stretched)	Depth (Number of Meshes)	Twine Size (Ply)	Guard Mesh (Size and Ply)	Type Hanging (Leadline)
$4\frac{1}{2}$	71	5	1 mesh-10 ply, 1 mesh-8 ply	2 mesh/hanging, skip 1
$5\frac{1}{2}$''	59	5	''	''
$6\frac{1}{2}$''	51	6	''	''
$7\frac{1}{2}$''	45	8	''	2 mesh/hanging, skip 0

Table 2 - Trammel-Net Specifications

Inner Net			Outer Net		
Mesh Size (Stretched)	Depth (Number of Meshes)	Twine Size (Ply)	Mesh Size (Stretched)	Depth (Number of Meshes)	Twine Size (Number)
$4\frac{1}{2}$''	124	5	18"	20	15
$6\frac{1}{2}$''	86	6	19"	19	15

on the corkline so that 100 fathoms of netting (stretched mesh) were hung on 50 fathoms of corkline. Trammel nets differed from the gill nets in the addition of large-mesh outer "walls," which enclosed the inner webbing. These outer walls of webbing were evenly spaced opposite to each other to allow fish to push the inner webbing through the walls and thus pocket themselves.

Except for the leadline, the nets were made of nylon, and dyed green or grey-green to make them less conspicuous in the water. The webbing was constructed of bonded double-knotted salmon twine, headlines and corklines of 3-strand spun rope, and breastlines, seizings, and hangings of spun twine.

SELECTIVITY OF MESH SIZE

The manner in which albacore were captured during the summer cruise of the John R. Manning was not the same for the various meshes of a set. Smaller meshes of the gill nets captured fish more by entangling than gilling and the trammel meshes captured entirely by entangling rather than pocketing. When a set of nets was retrieved, the tension placed on the shackle coming aboard was sufficient to disentangle the fish and those not properly gilled sometimes fell out of the net before reaching the vessel. Table 3 indicates that more fish were lost from the smaller meshes than from the nets of larger meshes during retrieving. The absence of fish loss from the trammel mesh probably attests to the entangling efficiency of its multiple meshes.

Table 3 - The Number of Fish Lost per Mesh Size of Gill Net as the Retrieved Gear Neared the Vessel

(The figures in parentheses give the loss per shackle.)

Mesh	$4\frac{1}{2}$"	$5\frac{1}{2}$"	$6\frac{1}{2}$"	$7\frac{1}{2}$"
Number Lost .	7(0.21)	11(0.25)	5(0.09)	1(0.03)

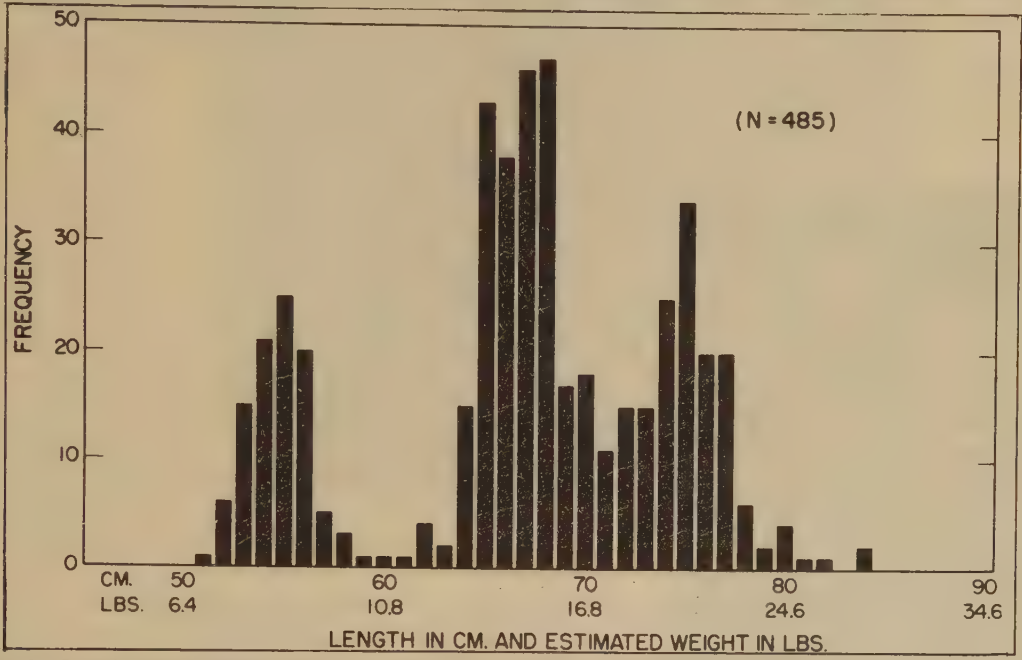

Fig. 3 - Length frequencies and estimated weight of albacore tuna taken in gill nets during cruise 32 of the research vessel John R. Manning.

Three size groups of albacore covering a size range of 51 cm. (20 inches) to 84 cm. (33 inches) fork length (fig. 3) were sampled by the gill nets of the John R. Manning. Table 4 shows that over this size range a progressive shift toward larger

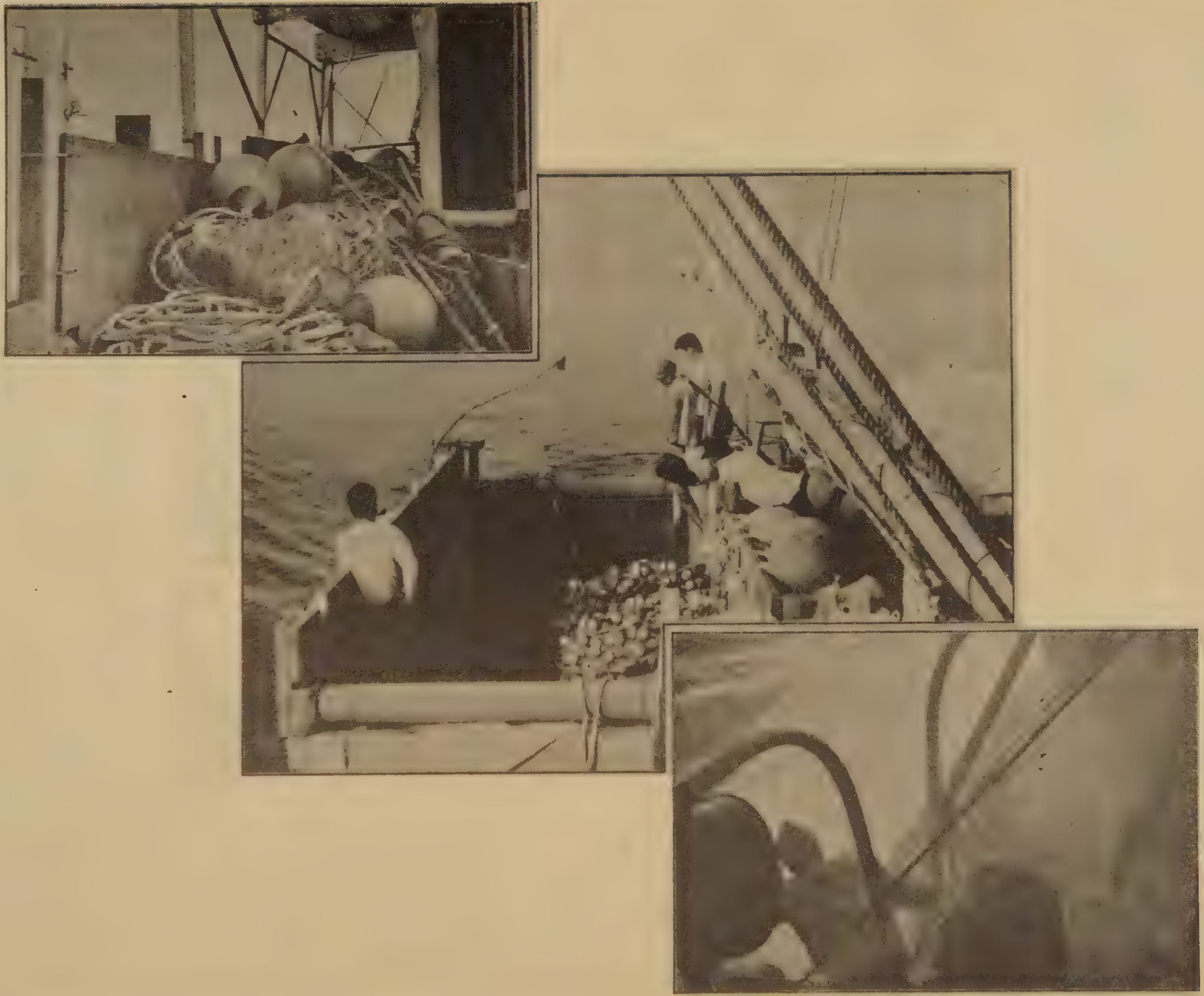

Fig. 4 - Upper left panel: Gill nets stacked in the bins of the charter vessel Paragon. Middle panel: Laying gill nets, John R. Manning. Bottom panel: Retrieving gill nets in the North Pacific, John R. Manning.

fish accompanied an increase in mesh sizes from $5\frac{1}{2}$ inches to $7\frac{1}{2}$ inches. This shift was so great in the case of the largest mesh that the small size group (51-60 cm. or 20-23 inches) was almost missing from the catch. In contrast, the smallest mesh ($4\frac{1}{2}$ inches) captured fish from all three size groups sampled (51-60 cm. or 20-23 inches, 61-70 cm. or 24-28 inches, and 71-80 cm. or 28-31 inches) and small fish were not emphasized in the catch. As in the case of the trammel nets it appeared that the $4\frac{1}{2}$-inch mesh captured albacore entirely by entangling.

Table 4 - Length Frequency of Albacore per Mesh Size

Shackel	Fork Length in cm.																																		Totals
	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	
$4\frac{1}{2}$	-	-	1	3	2	6	-	-	-	1	-	-	-	2	5	8	4	3	4	-	1	-	1	3	3	5	3	1	-	-	-	-	-	1	57
$5\frac{1}{2}$	-	6	10	8	7	4	2	1	-	-	-	1	1	2	5	-	6	8	3	2	2	2	1	4	5	-	3	-	-	-	-	-	-	-	83
$6\frac{1}{2}$	1	-	2	9	14	6	3	2	-	-	1	3	-	7	19	18	21	16	6	11	6	4	4	4	12	6	4	1	-	2	-	-	-	-	182
$7\frac{1}{2}$	-	-	-	-	1	-	-	-	-	-	-	-	1	3	10	8	12	19	3	5	2	6	7	5	8	5	8	3	2	2	-	-	-	1	111
Trammel	-	-	2	1	1	4	-	-	1	-	-	-	-	1	3	4	3	1	1	-	-	3	2	7	5	4	2	1	-	-	1	-	-	-	47
Totals	1	6	15	21	25	20	5	3	1	1	1	4	2	15	42	38	46	47	17	18	11	15	15	23	33	20	20	6	2	4	1	-	-	2	480

The progressive shift in fish size with increase in mesh size and the ability of the larger meshes to gill rather than entangle affect the commercial potentialities of the individual meshes. Of the meshes fished, the $7\frac{1}{2}$ inch stands far above the others in efficiency in catch when measured both by numbers and by weight of fish caught per shackle (table 5). This efficiency is further emphasized in that average fish size is greater for this mesh and almost all fish taken exceeded 10 pounds. Below this size albacore are often not acceptable to canners. Another attractive feature of the larger mesh is a lower shark catch per shackle, for while shark damage to albacore during the cruise was negligible, their removal from the nets required time and resulted in broken meshes. Presumably, the larger mesh of the $7\frac{1}{2}$-inch net permitted the slender form of the great blue Prionace glauca (Linnaeus)--the most abundant shark--to pass through rather than gill in the net.

Table 5 - Catch per Mesh Size Within the Area of Abundance (42°-46° N., 175°-155° W.)
(Figures in Parentheses were Determined from the Four Largest Catches[1])

Mesh Size (Stretched Measure)	Albacore		Weight in Pounds			Percentage of Albacore Above 10 Lbs.	No. of Sharks	
	Total Number	Number Per Shackle	Total	Per Shackle	Avg. Fish		Total	Per Shackle
$4\frac{1}{2}$''	(35) 57	(4.4) 2.0	855	(61) 30	$15\frac{1}{2}$''	79	57	1.9
$5\frac{1}{2}$''	(48) 84	(4.8) 2.2	1,054	(56) 28	$12\frac{1}{2}$''	54	57	1.4
$6\frac{1}{2}$''	(105) 186	(8.0) 3.7	2,642	(110) 56	$14\frac{1}{2}$''	80	56	1.1
$7\frac{1}{2}$''	(78) 118	(9.8) 4.2	1,929	(172) 69	$17\frac{1}{2}$''	99	22	0.7
Trammel	(25) 47	(5.0) 2.8	773	(78) 45	$16\frac{1}{2}$''	80	28	1.6

[1] Included in all figures is the catch for a set which took 10 albacore, but had a soaking time of only $2\frac{1}{2}$ hours.

On the basis of the above data, it is not possible to establish what mesh size would be best for fishing albacore commercially with gill nets in the central North Pacific, since our most efficient mesh was also the largest used. Powell et al (1952) captured albacore of the same size range in the eastern North Pacific using gill nets with mesh sizes of $7\frac{1}{2}$ inches, $8\frac{1}{2}$ inches, and $9\frac{1}{2}$ inches. His data showed that the $7\frac{1}{2}$-inch and $8\frac{1}{2}$-inch meshes fished with about the same success but the $9\frac{1}{2}$-inch mesh experienced a considerable decrease in catch. From Powell's and our own observations we conclude that the most efficient mesh size with respect to commercial gain would lie between $7\frac{1}{2}$ inches and $8\frac{1}{2}$ inches.

As the gill net was retrieved aboard the John R. Manning, an observer recorded the depth of each albacore in the net by arbitrarily dividing the total depth of the net (by sight) into thirds. A summary of these observations showed that during the cruise, 41 percent of the catch was taken in the upper third of the net, 35 percent in the middle, and 24 percent in the lower third. Thus, most of the fish were captured near the top of the net, but the one quarter near the bottom would suggest that if the net had been deeper, more fish might have been taken. Powell et al (1952) also recorded the depth distribution of fish in their nets and found that the majority of the albacore were taken near the surface between 1 and 3 fathoms in depth, that is, within the depth (4 fathoms) of the POFI nets. However, several fish were captured near the leadline and it is possible that in some instances the 100-mesh nets, which are about twice the depth of the POFI nets, did not fish the entire vertical distribution of albacore. The depth of net from which the greatest commercial advantage could be realized cannot be ascertained from the above data since such factors as cost of netting, ease of retrieving, net storage area aboard the vessel, etc., must be considered. Without such considerations, a compromise between the gears used by Powell and POFI or 75 meshes would not seem unreasonable.

SUMMARY

If we consider our data comparable with that of Powell, the most productive net with which to fish albacore commercially in the central North Pacific would have a mesh size between 7½ inches and 8½ inches and a depth of 75 meshes.

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Franklin Gull in the Central Pacific.—While on an oceanographic and tuna-fishing cruise to the Marquesas Islands in May and June of 1958, the author sighted a pair of Franklin Gulls (*Larus pipixcan*) at Taiohae Bay, Nuku Hiva. The birds were first seen on May 15 and remained in Taiohae Bay until May 25 when they disappeared. Both birds were black-headed, in typical nuptial plumage; the distinctive black markings across the white tips of the wings were clearly observed. In a search of the available literature on birds of the Marquesas, we failed to find any mention of the Franklin Gull.

Two representatives of this species were also sighted in Hawaiian waters at about the same time. On May 30, 1958, Henry Hasegawa collected a specimen of Franklin Gull about 2 miles off Kekaha Light, Kauai. The gull was in company with a flock of terns and shearwaters which were working over a school of skipjack tuna. The author examined the specimen after it had been mounted by a local taxidermist and compared it with the figures and description provided by Dwight (Bull. Amer. Mus. Nat. Hist., 52, 1925). This bird was also in typical breeding plumage and even in the preserved state showed a slight rosy "bloom" on the breast. This coloration was reported to be considerably more prominent on the freshly collected specimen. On June 14, Mr. Hasegawa saw a second Franklin Gull in West Loch of Pearl Harbor, Oahu; this bird was not collected, however.

Mr. Hasegawa is an engineer on a tuna fishing vessel and is thoroughly familiar with the common sea birds of the Hawaiian area. He collected the gull because he had never seen a bird of this type before in Hawaii and realized that its presence here was worth verifying.

The only other recent sighting of a Franklin Gull in Hawaii was that by John W. Slipp who saw and photographed a single specimen near Barber's Point, Oahu, on May 16, 1953 (Elepaio 14(1), 1953:7). The A.O.U. Check-list (1957:227) indicates that the Franklin Gull is "Accidental in Hawaii (Maui), ..." This statement was probably based on W. A. Bryan's list of Hawaiian birds in the St. Louis College collection (Auk, 18, 1901:382–387) which describes a specimen in immature plumage, most likely taken on Maui but with collection data lacking. The author has been an observer of Hawaiian birdlife for nine years but has not sighted the species in Hawaii in that period.—JOSEPH E. KING, *Honolulu, Hawaii, November 20, 1958.*

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A NEW METHOD OF HANDLING LONGLINE GEAR
A DESCRIPTION OF POFI "TUB" GEAR

by

HERBERT J. MANN

Pacific Oceanic Fishery Investigations, Honolulu, Hawaii, U.S.A.

stract

Modifications to Japanese-type longline gear, by the introduction of a large, rotating tub from which the line is handled, have ulted in a considerable saving in manpower. Conventional gear can be operated in this manner with few changes. Instead of using ividual baskets of line which must be separated and joined together for each day's fishing, a continuous mainline is set from, and hauled o, a wooden storage drum. This innovation is the product of continuing studies to increase the efficiency of longline gear.

Une nouvelle méthode de manipulation des palangres Description de la baille à lignes POFI

sumé

On a obtenu une importante économie de main-d'oeuvre grâce à des modifications apportées aux palangres japonaises par l'introction d'une grande baille tournante dans laquelle se trouvent les lignes. L'engin habituel peut être manoeuvré de cette façon avec peu de ngements. Au lieu d'utiliser des paniers individuels de lignes qui doivent être désassemblées et réassemblées chaque jour pour la pêche, on t à l'eau et on récupère dans une baille de bois une ligne principale continue. Cette innovation est le résultat de recherches en cours pour gmenter le rendement des palangres.

Nuevo método para manipular palangres. Descripción del "tambor" POFI para enrrollar palangres

tracto

Las modificaciones introducidas a los palagres de tipo japonés mediante el uso de un "tambor" rotatorio desde el cual se manipula e aparejo de pesca economiza bastante mano de obra; además permite usar unidades de tipo convencional con sólo pequeñas modificaciones. lugar del empleo de varias cuerdas madres que es necesario unir y separar en cada salida, se procede a calar y a levantar una sola almanada en el "tambor" de madera. Esta innovación es el producto de continuos estudios para aumentar la eficacia de los palangres.

THE Pacific Oceanic Fishery Investigations (POFI) of the U.S. Fish and Wildlife Service has found longlining to be an effective means of catching nas in the relatively baitless waters of the central cific. This report describes a new method of fishing ngline gear recently developed at POFI following a ggestion by Mr. A. K. Akana Jr., POFI fleet supervisor.

The longline gear previously used by POFI was copied m conventional Japanese designs and, although equate as a sampling tool for exploratory fishing, it quired too many men, by American standards, to be al for commercial use. The so-called "tub" gear scribed below is the most successful effort to date to prove the efficiency of gear in this respect, in that it mits a material reduction in the manpower required operate longline gear.

The essence of the tub method lies in a novel means handling the mainline. Instead of the individual skets of conventional gear, which must be separated d joined together for each day's fishing, tub gear s a mainline of one continuous length which is shot m and hauled into, a large wooden storage drum or ub". Branchlines and floatlines are removed from the mainline as they come aboard and are reattached during shooting operations.

The tub method requires only minor changes in the design of conventional longline gear. Standard POFI gear, or any longline with detachable branchlines and floatlines, may be used by adding "D" rings (described below) to the mainline.

DESCRIPTION OF THE GEAR

The gear is of a flexible design so that it can be altered readily to meet the changing requirements of an exploratory fishing programme. Components are detachable and can be assembled so as to fish varying numbers of hooks at different depths.

Shown in fig. 1 is a schematic representation of a single unit, or basket, of POFI gear of the latest type. Sixty to a hundred such baskets are joined together to make a fishing set.

Mainline

The mainline of each unit is made up of fourteen identical sections knotted together by double sheet bends. Each

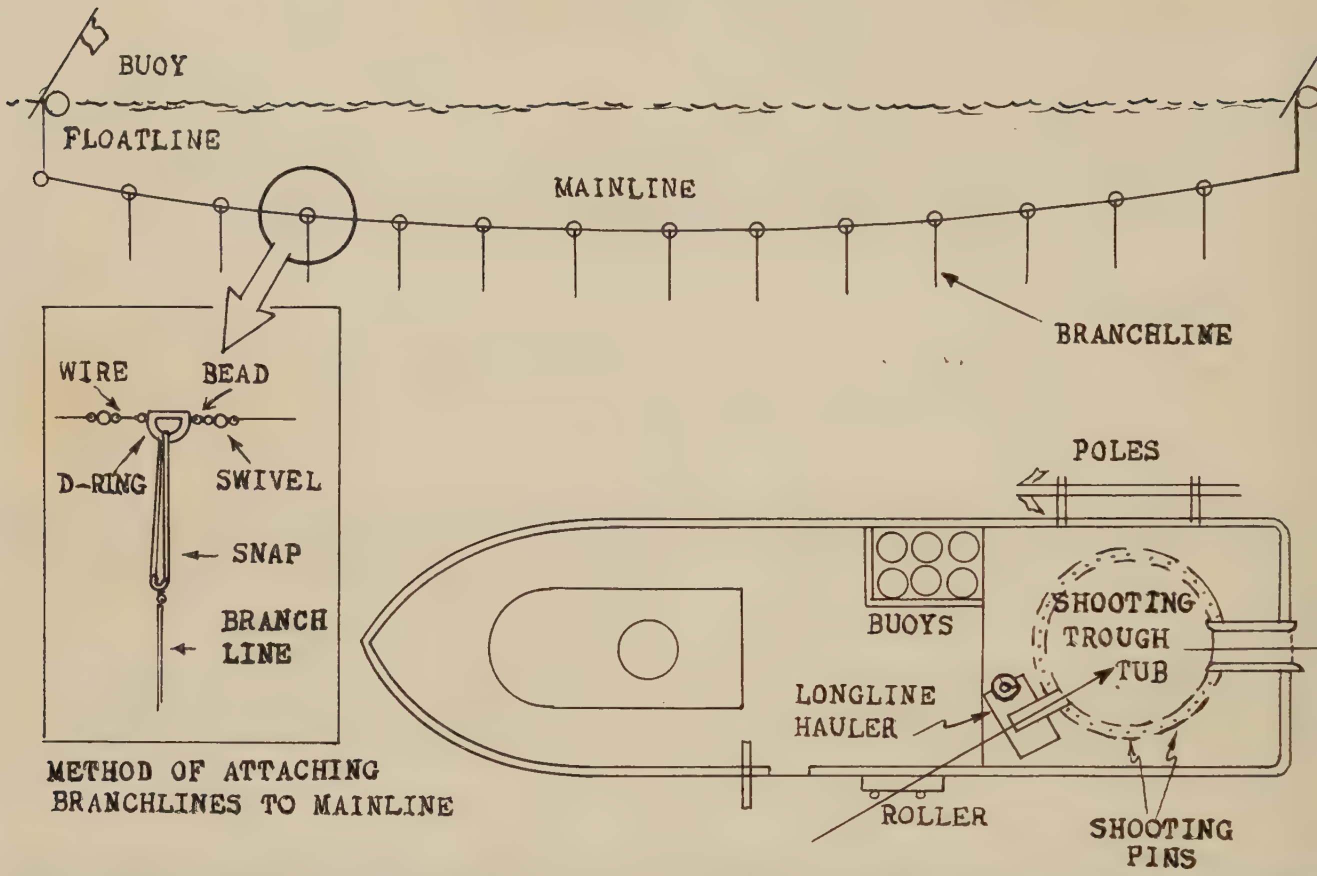

Fig. 1. Schematic drawing showing the arrangement of a single unit, or "basket", of POFI longline gear, and the location of the lin storage tub on the stern of the vessel.

section consists of a 15 fm. length of preserved 261 thread hard-laid cotton twine with an eye splice in one end and a wire bridle with swivels, "D" ring, and pigtail at the other. Baskets are joined by a clover-leaf knot which is formed with an extra loop for attachment of the floatline.

Attachment of branchlines

The branchlines are attached to the mainline by the "AK" snap and "D" ring arrangement shown in fig.1. The "D" ring eliminates a troublesome defect of old gear. Formerly, "AK" snaps were clipped directly to a wire bridle. This type of attachment permitted the branchline to swivel around the mainline and prevented tangles when gear was being hauled aboard ship. But sometimes it failed to function properly when large fish pulled the branchline parallel to the mainline. At acute angles of pull, the snap ceased to have any swivelling action and sometimes was pulled out of shape or broken. The "D" ring maintains proper swivelling action. Rings are fabricated from stainless steel tubing with a lower section formed in a U shape and welded to the upper, straight tube section through which the bridle is rove. The wire bridles are made of a 6 in. length of 3/32 in. diameter 7×7 stainless steel wire rope with swivels connected to each end by means of Nicopress fittings. These fittings consist of malleable copper sleeves which are pressed on the wire by a ha tool. Brass beads threaded on the wire on both si of the "D" ring act as miniature thrust bearings, a aid the swivelling action of the "D" ring. The br swivels relieve torque on the mainline which occ when the line is being brought in by the hauler.

Branchlines, snoods and hooks

The branchlines are made of 2 fm. lengths of 261 thre line. An "AK" snap is spliced into the upper e The lower end terminates in an eye splice for securi snood and hook. The snoods are fashioned of 6 lengths of ·066 in. diameter 7 strand galvanised wi The upper end of the snood is fitted with a section $\frac{3}{8}$ in. rubber tubing which serves as chafing gear. T hooks, 8/0 or 9/0 tinned, are of a special shape w bent shank which allows them to hang in line w the snood.

Floatlines

Floatlines are made from 10 fm. lengths of 261 thre line. The lower end of each line has an "AK" snap attachment to the mainline. Snaps are clipped to loc in the line, rather than to "D" rings, since it has be found that "D" rings and wire bridles do not hold under the incessant jerking caused by the rise and of floats with sea and swell.

rage tub

own in fig. 1 is a schematic drawing of the wooden used for storage of the mainline. The experimental del used aboard the Fish and Wildlife vessel, "John Manning", is a double-walled plywood cylinder asuring 12 ft. in diameter and 4 ft. in depth. The pacity is sufficient for the storage of 100 baskets of r. For greater ease in shooting the tub is mounted r the stern of the vessel, but adequate space between and railing is left all around. The drum is supported the centre by a heavy bearing bolted to the deck; outer edge runs on cast iron rollers of the type used support the turntable of a purse seining vessel. inforcing bands of 3 in. strap metal are welded around outside of the tub for extra support, and 33 stainless el shooting pins are spaced at equal intervals inside the .

The gear is hauled by means of a longline winch of nventional Japanese design. Electrically powered by h.p. motor, the winch brings the line in at a maximum e of about 1,000 ft./min. and coils it down automatic- y with only slight assistance from the winch operator. e hauler is mounted so that the line is thrown just er the edge of the tub.

The shooting trough, similar in design to that used the Northwest Pacific halibut fishery, is a demountable et metal form used to guide the outgoing mainline ring shooting.

ERATION OF THE GEAR

eparation

fore sailing, baskets of mainline are joined together d fed through the Japanese line hauler into the tub. attempt is made to coil the line down uniformly o regular piles, but it is deflected by hand so that it evenly distributed in thickness over the bottom of tub. As the "D" rings pass through the hauler, y are caught and threaded upon the shooting pin arest the hauler. All fourteen rings of one basket placed on the same pin and the knot marking the d of the basket is looped on top. The tub is then ned by hand until the next shooting pin comes in e with the winch. To avoid piling up the line, the skets are spaced on every other pin; when the tub s completed one revolution, a second and finally a rd layer of line is laid over the first so that 99 baskets held on 33 shooting pins. The tub is covered with canvas tarpaulin to prevent the line from being dis- ced in rough weather.

ooting

hen shooting the tub is rotated by hand until the permost basket comes under the shooting trough. e vessel is steered on a steady course at a speed of up 9 knots. The buoy and floatline, marking the end of set, are attached to the mainline, which in turn is through the trough, and the assembly is thrown erboard. Thereafter the drag of the gear pulls the inline overboard as the vessel proceeds.

Hooks are baited with sardines, *Sardinops caerulea* (Girard), or herring *Clupea pallasii* (Valenciennes). Individual branchlines are attached to the mainline by clipping the "AK" snap at the upper end of the branchline to the uppermost "D" ring. They are then laid in the shooting trough one by one with the hook and bait dangling overboard. Floatlines are attached in the same manner. As the end of each basket leaves the shooting pin, the tub is turned to keep successive baskets in line with the shooting trough.

Hauling

The gear is hauled through side rollers on the starboard side of the vessel. The mainline is led through the hauler and coiled into the tub. As branchlines come aboard, the winch is stopped momentarily and the "AK" snaps are removed from the "D" rings. The branchlines are coiled in specially built plywood boxes and are stowed with hooks exposed on one side and with the "AK" snaps held by clips on the other. Fish are gaffed and brought aboard through an opening in the bulwark. The line is stowed in the tub as described before, with three baskets of "D" rings being placed upon each pin.

Broken or tangled portions of mainline are removed by unknotting the line section junctions, repaired, and joined to the end of the mainline when fishing finishes. Because the sections are identical they need not be restored to their original positions.

CONCLUSIONS

Tub longlining, in particular, seems applicable to small vessels carrying a limited number of men.

The saving in labour is considerable. Since a basket of POFI gear weighs about 40 lb. when wet and a day's set may consist of up to 100 baskets, about 4,000 lb. of wet line would have to be cleared out and restowed by hand for each day's fishing, when using conventional methods. The POFI tub method eliminates all man-handling by flaking the line directly into the tub.

Five men were found sufficient to operate the gear, as against a crew of 11 men required for conventional gear. Both methods require, for each basket of line, about 1½ min. for shooting and 3½ min. for hauling.

Some difficulties in operation have been experienced, the most troublesome being excessive wear and tear on the mainline, due to the "D" rings running at high speed through the overside rollers and longline hauler. At high hauling speeds, "D" rings strike the rollers or hauler with enough force to bend the rings or break wire bridles. Much needed is a method of joining branchlines to the mainline by a system which permits swivelling freely in any direction but which offers little resistance to passage through the line hauler.

One difficulty anticipated, which failed to materialize, was fouling of the mainline during shooting operations. Provided that the shooting trough is properly designed, the outgoing mainline runs smoothly in it and fouling is less than when shooting by conventional methods.

All POFI tubs are rotated manually. Mechanical rotation has not yet been installed but, if used commercially, powered tubs should increase efficiency.

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UNDER THE LEADERSHIP OF THE LATE PROFESSOR JOHANNES SCHMIDT

DANA-REPORT No. 50.

DESCRIPTIONS OF *EUTHYNNUS* AND *AUXIS* LARVAE FROM THE PACIFIC AND ATLANTIC OCEANS AND ADJACENT SEAS

BY

WALTER M. MATSUMOTO
U. S. FISH AND WILDLIFE SERVICE

WITH 31 FIGURES IN THE TEXT

PUBLISHED BY THE CARLSBERG FOUNDATION

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(This List to be continued on page 3 of the cover).

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OCEANOGRAPHICAL EXPEDITION ROUND THE WORLD 1928—30
AND PREVIOUS "DANA"-EXPEDITIONS
UNDER THE LEADERSHIP OF THE LATE PROFESSOR JOHANNES SCHMIDT

DANA-REPORT No. 50.

DESCRIPTIONS OF *EUTHYNNUS* AND *AUXIS* LARVAE FROM THE PACIFIC AND ATLANTIC OCEANS AND ADJACENT SEAS

BY

WALTER M. MATSUMOTO
U. S. FISH AND WILDLIFE SERVICE

WITH 31 FIGURES IN THE TEXT

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INTRODUCTION

The tunas are of special interest to marine ecologists and fishery biologists. They constitute a major element of the fish fauna of tropical and subtropical seas the world over, and they are of major economic importance, contributing an important share of the world protein resources. Information on the distribution and abundance of tuna larvae is essential to our knowledge of the life histories of the tunas. Variations in larval distribution may possibly serve as an index to the distribution of adults which is often difficult or impossible to assess by the usual sampling methods.

A related problem involves the difficulty of locating spawning grounds through gonad examination, principally because ripe females are only seldom taken, even in areas where spawning is known to occur and where commercial fisheries exist. The infrequent capture of ripe females may be due to very rapid development of the eggs within a brief time interval in the final stage of maturity, or perhaps because females with ripe eggs may undergo changes in feeding habits during this period. The latter may be one reason for the preponderance of males in the catches of various tunas (Murphy and Shomura, 1953a, 1953b, and 1955) and may also account for the rarity of capture of females with near, or running, ripe gonads in the Hawaiian skipjack fishery (Brock, 1954). These problems may be approached by examining the tuna eggs and larvae taken in plankton nets, provided the eggs and larvae can be identified readily and accurately. The eggs and larvae are largely planktonic at this stage of development, and the planktonic catches are not dependent upon the feeding habits of the spawning females.

The problem of identifying tuna larvae is an unusually perplexing one. The difficulty lies primarily in obtaining the juveniles which are indispensable to bridge the gap between the postlarval and adult stages of development. In a few areas, such as off the Pacific coast of Central America, the Gulf of Mexico and the central Pacific islands (Line and Phoenix Islands), juveniles of yellowfin (*Neothunnus macropterus*), skipjack (*Katsuwonus pelamis*), little tunny (*Euthynnus yaito*, *E. alletteratus*, and *E. lineatus*) and frigate mackerel (*Auxis thazard*) have been captured under night-lights, but the occurrence of juveniles in other areas is unknown. Practically nothing is known of the distribution of juveniles of species not mentioned above. Consequently, although it is possible to catch sufficient numbers of tuna larvae in plankton nets, it is extremely difficult to identify the larvae at the species level because of the scarcity of juveniles in collections.

There would be less difficulty in identifying the young, if tuna eggs could be fertilized artificially and a growth series of larvae obtained. Judging from the dearth of published reports in this field of investigation, and from our own lack of success in capturing ripe adults, we believe that the identification of tuna larvae by this method is highly improbable. Perhaps the closest approach to this method is the work by Sanzo (1932a, 1932b, and 1933), who hatched and reared tuna eggs taken in plankton nets. Inasmuch as the eggs were collected in areas in which several species of tuna spawn, the specific identity of these larvae was suspect.

The purpose of this paper is to describe the larvae of two genera of tuna, *Euthynnus* and *Auxis*, the adults of which have only minor commercial importance at the present time. The bulk of the material used was furnished by the Carlsberg Foundation, Copenhagen, Denmark, from collections made by the "Dana" and other Danish vessels from 1911 to 1938. Other specimens were obtained from the California Department of Fish and Game, the Inter-American Tropical Tuna Commission, and the Gulf Fisheries Exploration and

Gear Research and the Pacific Oceanic Fishery Investigations[1] (POFI) of the United States Fish and Wildlife Service. The years in which collections were made, names of vessels, number of stations with tuna specimens, number of hauls with tuna specimens, and total number of tuna specimens captured are summarized in table 1.

Table 1. Specimens of *Euthynnus* and *Auxis* obtained from various sources.

Source of material					Locality of capture	Species	No. of specimens	Size range in millimeters
Carlsberg Foundation, Copenhagen, Denmark								
	Year	Vessel	No. of stations with tuna specimens	No. of hauls with tuna specimens				
	1912	"Florida"	1	1	Mid-Atlantic Ocean	*Auxis* II[1]	1	7.5
	1920–22	"Dana"	29	62	Western and Mid-Atlantic, Gulf of Mexico, and Caribbean Sea	*Auxis* I[1]	521	3.7–60.0
						Auxis II[1]	84	3.5–8.0
						Euthynnus alletteratus	47	4.6–11.6
						Euthynnus lineatus	132	5.0–18.6
						Euthynnus (sp. unknown)	6	3.7–6.0
	1928–30	"Dana"	46	133	Mediterranean Sea, Gulf of Mexico, East Indies, Atlantic, Pacific and Indian Oceans	*Auxis* I[1]	908	3.5–36.0
						Auxis II[1]	677	3.7–8.0
						Euthynnus alletteratus	2	5.0, 6.5
						Euthynnus lineatus	4	5.0–7.5
						Euthynnus yaito	238	3.5–12.5
						Euthynnus (sp. unknown)	34	3.7–10.7
	1933	"Pacific"	1	1	South China Sea	*Auxis* II[1]	7	4.5–8.5
	1937	"Pacific"	1	1	East Indies waters	*Auxis* II[1]	1	5.5
U. S. Fish & Wildlife Service, Gulf Fisheries Exploration, Pascagoula, Mississippi					Gulf of Mexico	*Auxis thazard* (?)	140	19.5–84.0
						Euthynnus alletteratus	118	11.5–94.3
U. S. Fish & Wildlife Service, Philippine Fishery Program					Philippine waters	*Euthynnus yaito*[2]	40	33.5–178.0
Inter-American Tropical Tuna Commission, La Jolla, California					Pacific Ocean off Central America	*Auxis thazard*	21	15.0–50.0
California Department of Fish & Game, San Francisco, California					Pacific Ocean off Central America	*Euthynnus lineatus*	2	21.0, 27.0
						Auxis thazard	16	11.0–28.0

[1] *Auxis* I and II are discussed on pages 21 to 25.
[2] Specimens previously examined by WADE (1949) and now deposited at POFI laboratory.

The research leading to this paper was performed as a regular part of the author's duties as Fishery Research Biologist of the United States Fish and Wildlife Service, Pacific Oceanic Fishery Investigations, Honolulu, Hawaii.

METHODS

The method of study followed was the same as that used in a previous paper (MATSUMOTO, 1958a). Because the smaller specimens were still in the initial stages of development and lacked many of the characters by which the adults are identified, other characters had to be found. Pigmentation in certain parts of the body appeared the most promising, therefore, this character was used as the basic criterion, supplemented by other character differences.

The larvae were first separated into various groups, each group with a distinctive pigment pattern. From each of these groups a size series of typical specimens was selected and, wherever possible, extended to include juveniles which were old enough for positive species identification. Several specimens of various sizes from each of these series were stained with alizarin, according to the method given by LIPMAN (1935), for studies on the formation of bones and spines. All the descriptions and counts presented here are based on observations on the left half of the body, unless otherwise specified.

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[1] Effective January 1959, the name of the Investigations was changed to Bureau of Commercial Fisheries, Biological Laboratory, Honolulu, Hawaii.

Because there may be disagreement with other authors on some of the terms used here, it would be well to define them. With tuna it is difficult to draw a line between the terms "larva" and "postlarva" because these fish do not pass through any well marked metamorphosis and the various organs develop gradually, some more rapidly than others. Therefore, for the sake of simplicity, all individuals with less than the full fin-ray counts, especially in the first dorsal fin, are considered larvae. This normally includes specimens 11 mm. or less in total length. Specimens between 12 mm. and approximately 18 mm. are considered postlarvae. In specimens within this size range the anal opening, which on smaller individuals is situated at less than half the distance from the pelvic to the anal fin origins, is relocated near the origin of the anal fin. All other young tuna larger than 18 mm. are classed as juveniles.

Other terms which might be misinterpreted are defined as follows:

1. Total or fork length: the body length measured from the tip of the snout to the fork of the tail when the tail is forked, and to the tip of the longest ray when the tail is not forked.
2. Caudal peduncle: the posterior part of the body between the last finlet and the base of the caudal fin.

GENUS *EUTHYNNUS*

Notes on Adults and Juveniles.

The taxonomy of the fishes of this group is in need of clarification. Much of the disagreement that exists can be traced to insufficient details in the original descriptions and to attempts by later workers to revise the genus on the basis of such descriptions. Some of the difficulties are due also to the indiscriminate establishment of species or subspecies whenever a slight external body difference was noted or whenever specimens were taken from different geographical localities. Fraser-Brunner (1950) recently revised the Scombridae on a worldwide basis, but despite this work and a previous study by the same author (1949), there is still some disagreement concerning the nomenclature of the several species of *Euthynnus.* Consequently, there is at present no single classification which is wholly accepted by the majority of workers.

Because the correct identity of the adults must be established before a larval or juvenile tuna can be assigned to a species, it is imperative that we examine and clarify the taxonomic position of the adults.

In 1915 Kishinouye described a specimen of *Euthynnus yaito* which was taken from the waters off southern Japan, and which he believed to be identical with Cantor's (1850) *Thynnus affinis.* The holotype of *affinis* was from Penang, most likely from the Strait of Malacca, but since Cantor described only the external appearance of the fish, it was impossible for Kishinouye to decide whether his specimen was identical with Cantor's. Fraser-Brunner (1949), however, noted that the type specimen from Penang had vomerine teeth which Cantor had failed to mention in his description. This character agrees with Kishinouye's observation on *yaito.* Wade (1950) examined a number of juvenile *Euthynnus* (33.5 to 178 mm. in length) taken from the waters around the Philippine Islands and the Celebes Sea in the East Indies, and identified them as *yaito,* after Kishinouye (1915). He made no mention of the presence of other *Euthynnus,* notably *affinis,* even though the specimens were taken in the general area where Cantor obtained *affinis.*

The author believes that Kishinouye's suspicion concerning the similarity of *E. yaito* and *T. affinis* may be correct. If so, the specific name *affinis* would have priority over *yaito.* However, because the description of *affinis* is inadequate, and because neither the type specimen nor other adult specimens of this species were available for examination, no definite statement concerning the nomenclature can be made. Therefore, the Indo-Pacific species is designated as *yaito* in this paper.

Kishinouye (1920) described another species, *E. lineatus,* which was taken off Manzanillo, Mexico. Although the description of this species was based on a single specimen, subsequent authors, Schaefer and Marr (1948) and Godsil (1954), found supporting evidence for its permanent establishment. These authors noted 37 vertebrae in *lineatus,* as compared with 39 in *yaito* and *alletteratus* (table 2). Other identifying characters include fewer fin rays in the second dorsal and anal fins. A survey of the literature reveals that *lineatus* usually has 11 rays in the second dorsal and 12 rays in the anal fins, whereas *yaito* and *alletteratus* normally have 13 rays in the second dorsal and 14 rays in the anal fin. Thus, the species designation of *lineatus* will be retained in this paper.

Table 2. Summary of adult characters from literature[1] and from observations by the author.

Character	*E. lineatus*	*E. yaito*	*E. alletteratus*
Vomerine teeth	Present, but weak	Present	Absent, but bony ridge evident
Gill rakers:			
Upper limb	7–11	7– 9	10–11
Angle	1	1	1
Lower limb	23–29	22–24	25–29
Total	32–41	29–34	36–41
First dorsal fin rays	14–15	14–16	14–16
Second dorsal fin rays	11–12; mostly 11	12–14; mostly 13	12–14; mostly 13
Anal fin rays	11–13; mostly 12	13–14; mostly 14	13–14; mostly 14
Vertebrae	20 + 17 = 37	20 + 19 = 39	20 + 19 = 39

[1] Godsil, 1954; Rivas, 1951; and Wade, 1950.

The Atlantic form, *E. alletteratus* (Rafinesque), requires no comment, since it is widely accepted as valid. It differs from *yaito* in the absence of vomerine teeth, and in the greater number of gill rakers on the first gill arch, being similar to *lineatus* in this respect.

Specimens of *E. alletteratus* from the Gold Coast seem to be somewhat controversial. There is a difference of opinion regarding the external markings of this species; Irvine (1947) states that "there may be some obliquely placed wavy stripes on the sides above the lateral line"; whereas Fraser-Brunner (1949 and 1950) depicts the same specimens, which he designated as *E. alletteratus aurolitoralis,* with definite crescentic markings along the dorsal part of the body above the lateral line. Godsil (1954) found in *lineatus* a progressive and continuous variation in markings from the normal to a pattern that approached the crescentic. A similar condition may occur in *alletteratus;* hence the crescentic markings of *aurolitoralis* Fraser-Brunner could be an extreme variation of *alletteratus.* Until more conclusive evidence in support of *aurolitoralis* as a distinct species is obtained, these fish are designated as *E. alletteratus* (Rafinesque).

Thus, unlike Fraser-Brunner, who separated the genus into 2 main species, each with a number of subspecies, the author believes that *Euthynnus* is composed of 3 species: *alletteratus, yaito* and *lineatus.*

The juveniles of each of the three species were identified without too much difficulty, since most of the adult characters were sufficiently developed. Of the 161 specimens of juvenile *Euthynnus* examined, 118 were identified as *alletteratus,* 40 were identified as *yaito,* and 3 were identified as *lineatus.*

All specimens of *alletteratus* within the range 18.5 mm. to 94.3 mm., had either 16 spines and 13 rays or 15 spines and 14 rays in the dorsal fins, the first combination representing the usual count. The number of spines in the first dorsal agreed with the count on adult *alletteratus* given by Rivas (1951). The anal rays numbered 14 on all the specimens. All 5 specimens stained in alizarin had 20 + 19 = 39 vertebrae. Although identical fin ray and vertebral counts were found in *yaito, alletteratus* was easily separated from *yaito* by its higher gill raker count. *E. alletteratus* larger than 40 mm. possessed 24 to 28 rakers on the lower limb of the first gill arch. These counts were within the range of 25 to 29 rakers found in the adults (table 2). On the other hand, *yaito* above 50 mm. had 22 to 23 rakers on the lower limb, and thus comparable to the adult counts of 22 to 24. Specimens of both species below 50 mm. had fewer rakers than the adult of the respective species; but in all cases *alletteratus* had a much higher count than *yaito.* The smallest *yaito,* measuring 35 mm., had 4 + 1 + 20 = 25 rakers, whereas *alletteratus* of comparable size had 7 + 1 + 24 = 32 rakers. Even the smallest *alletteratus*, measuring 25.5 mm., had a higher raker count (5 + 1 + 21 = 27) than the 35 mm. *yaito*.

It is generally believed that the adult *alletteratus* has no vomerine teeth. Therefore, the presence of vomerine teeth in many of the larger juveniles of this species was puzzling at first. Sixteen out of 39 specimens between 34 mm. and 94.3 mm. had no vomerine teeth. Of the remaining 23 specimens, 18 had 1 weak but distinct vomerine tooth, 3 specimens had 2 to 3 weak teeth, and 2 specimens had 4 fairly strong ones. The presence of these teeth in juvenile *alletteratus* contradicts the adult descriptions, but their presence may be only a temporary condition. It is conceivable that the teeth are eventually lost, resorbed, or become overgrown by osseous material and appear as the "bony ridge" noted by GODSIL (1954).

For juveniles of *yaito*, observations were made on the specimens collected and reported by WADE (1949), which are presently deposited at the POFI laboratory. Our identification agreed substantially with WADE's. The fin ray counts, as well as the vertebral counts, were identical with those of *alletteratus*, but the vomerine teeth were stronger and more numerous. The gill rakers, as mentioned earlier, were fewer than in *alletteratus* and *lineatus*. We had no specimens below 30 mm., but this did not unduly affect our larval identification.

Only 3 juveniles of *lineatus*, all taken off the Pacific coast of Central America, were available for examination. Two of these specimens were captured by the California Department of Fish and Game and one by the "Dana". The material previously collected in the same general area just mentioned and identified as *lineatus* by SCHAEFER and MARR (1948) was also available for study. This material included specimens ranging in lengths from 29 to 86 mm. Our 3 specimens of *lineatus* have 15 spines in the first dorsal fin and 12 rays in the second dorsal. The two larger individuals have 12 anal fin rays, whereas the smallest one has 13. The low ray counts in both the second dorsal and anal fins clearly identify them as *lineatus*. In addition to these characters, a 26 mm. specimen, which was stained, shows 20 + 17 = 37 vertebrae. The gill rakers (4 + 1 + 19 = 24) evidently are not developed completely, and there is a single strong vomerine tooth in each of the two larger specimens. Except for the gill rakers, these characters agree with the description of juveniles by SCHAEFER and MARR (1948) and with the description of adults by GODSIL (1954).

Thus, the 3 species of *Euthynnus* are clearly distinguishable down through the juveniles, which can be linked with the series of specimens taken in plankton nets.

Descriptions of Larvae and Postlarvae.

Euthynnus lineatus KISHINOUYE

The description of this species is based on 135 specimens of *E. lineatus*, taken in the waters off the Pacific coast of Central America by the "Dana" in 1920—22 and 1928—30.

The smallest specimen identified as *lineatus* measures 5.0 mm. (fig. 1). The general shape of the body resembles that of other tunas (MATSUMOTO, 1958a), and the head is relatively large (about 37 percent of the total body length). The mouth is large and contains about 8 teeth on each side of both jaws (an

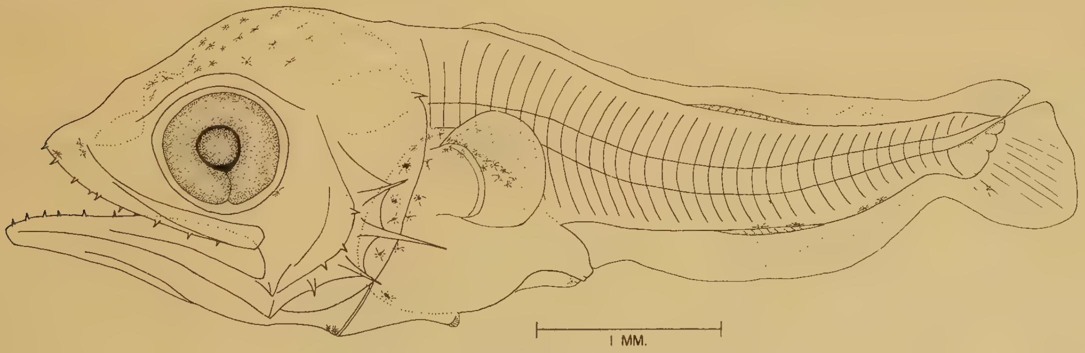

Figure 1. *Euthynnus* lineatus, 5.0 mm.

accurate count was not possible). The abdominal sac is short and triangular, and the anus is located near the middle of the body. No indications of spine or ray development in the first dorsal and other fins are noticeable, and the pelvic fins are just emerging as small, fleshy buds. The body contains 38 or 39 myomeres including the urostyle which is just beginning to turn dorsally.

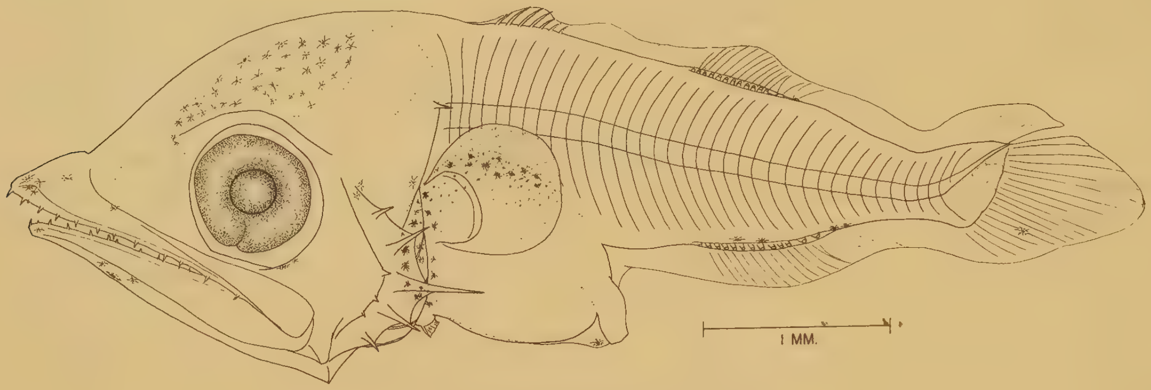

Figure 2. *Euthynnus* lineatus, 6.0 mm.

Pigmentation consists of chromatophores at the symphysis of the pectoral girdle and anterior to the anal opening. Each side of the brain is well pigmented with 12 to 15 chromatophores over the midbrain and 3 over the forebrain. Two chromatophores are present on the midventral line of the body along the base of the anal fin, and 2 more are seen faintly in the region of the middle anal "finlets". The lower jaw is unpigmented at this stage of development.

The body parts undergo very rapid growth, which is already evident in a 6.0 mm. specimen (fig. 2). Five short spines are visible in the region of the first dorsal fin and posterior to these, 2 more are beginning to develop. The second dorsal and anal fin rays are poorly developed and are difficult to distinguish, but about 11 pterygiophores are observable. The caudal fin consists of 17 rays.

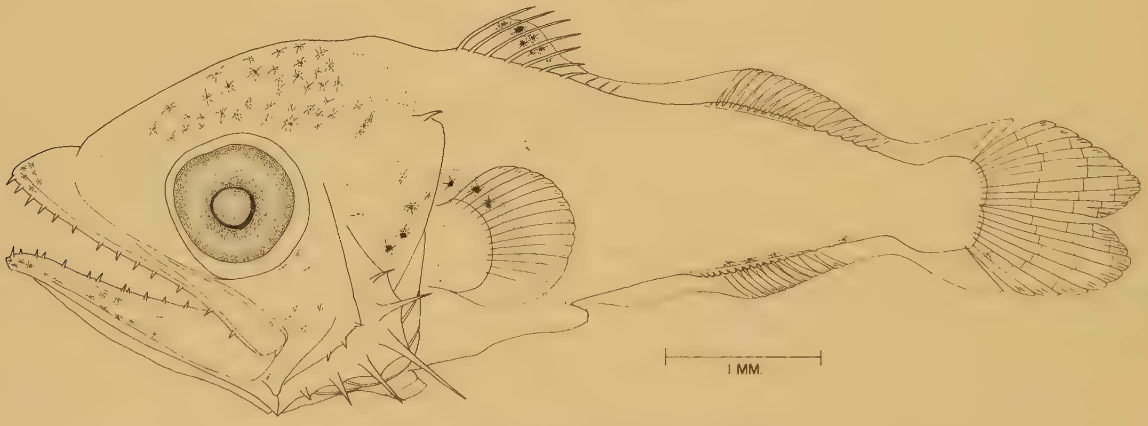

Figure 3. *Euthynnus lineatus*, 7.1 mm.

The chromatophores over the forebrain and midbrain have increased in number, but the pigmentation on the caudal region remains unchanged. Three or 4 chromatophores are present near the middle of the lower jaw.

A 7.1 mm. specimen (fig. 3) shows further developmental changes. The first dorsal fin consists of 7 definite spines, the 6 anterior ones being the slightly greater in length. Three additional weak spines are beginning to develop. The fin rays are poorly formed, but 11 pterygiophores are developed in the second dorsal fin and 12 in the anal fin. Similarly, about 5 indistinct basal elements of the dorsal finlets and 2 basal elements of the anal finlets are beginning to develop. The caudal fin, which is beginning to fork, has

18 well-developed rays, and the number of myomeres (38—39) is identical with that of the previous specimens.

Some striking changes are seen in the pigmentation. The first dorsal fin now has 6 large chromatophores between the second and sixth spines, and the first interspinal membrane is lightly tinged. In addition to the chromatophores at the tips of the upper and lower jaws, there are 7 more along the anterior two-thirds of the lower jaw. Pigmentation over the forebrain and midbrain is more extensive, and several small chromatophores are present on the opercle posterior to the angle of the jaw. Although the figure does not show them, 2 small chromatophores are present at the symphysis of the pectoral girdle.

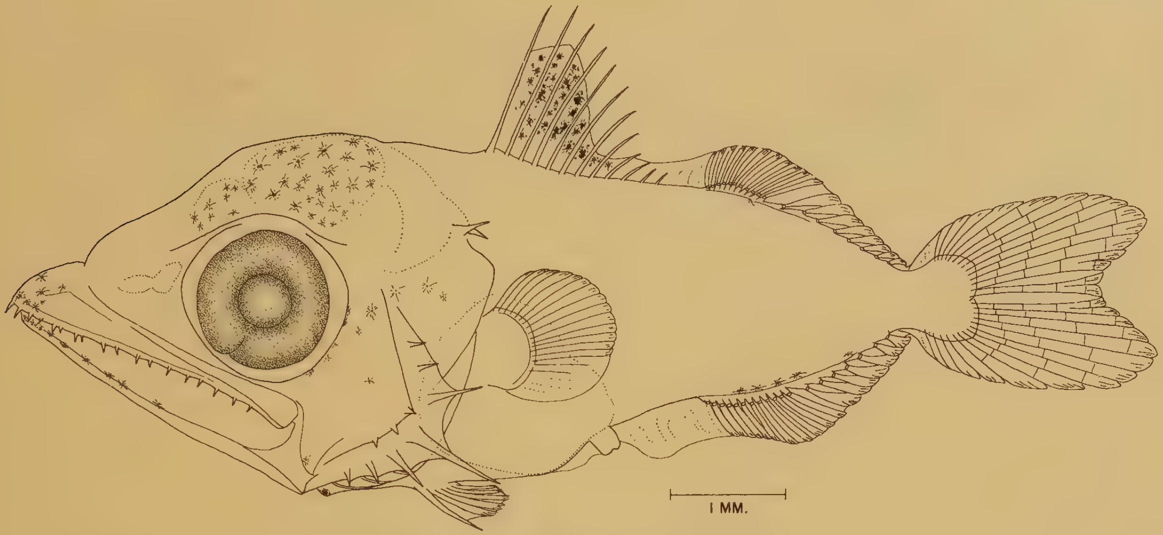

Figure 4. *Euthynnus lineatus*, 9.3 mm.

The most noticeable difference between the previous specimen and the 9.3-mm. specimen (fig. 4) is the development of the fins. The first dorsal fin consists of 12 well-developed spines; the longest one being about 78 percent of the body depth at the origin of the second dorsal fin. Elongate dorsal spines at this stage of development are not limited to this species alone. Specimens of *alletteratus* and *yaito* also show similar development, and it may be assumed that the spines grow at a relatively faster rate than the total body length until the individual is between 9 mm. and 12 mm. in length. The second dorsal fin consists of 11 rays and the 8 finlets following it are not fully developed; each finlet being attached to its neighbor by persistent elements of the median fin membrane. The first finlet is also attached to the last ray of the second dorsal fin. The anal fin, with 12 rays, and the 7 finlets following it are also connected in a similar way. The enlarged pelvic fins are almost completely developed, and the pectorals now have about 14 distinct rays.

Pigmentation on the first dorsal fin extends over the first 8 interspinal membranes and is generally concentrated on the outer two-thirds of the fin. A single small chromatophore is present near the base of the last ray of the second dorsal fin, and pigmentation on other parts of the body remain relatively unchanged. The myomere count is 38 or 39.

The body of the 10.6-mm. specimen (fig. 5) is beginning to resemble that of the juvenile. The abdominal sac has elongated, and the anal opening is only slightly anterior to the anal fin origin. The unpaired fins are almost fully developed and consist of 15 spines, 12 rays, and 8 finlets in the dorsal, and 11 rays and 7 finlets in the anal. The caudal fin contains the same number of rays, whereas the pectoral fin now consists of 20 well-developed rays.

Pigmentation over the forebrain and midbrain is more intense, but remains generally unchanged on other parts of the head, on the first dorsal fin, and at the bases of the second dorsal and anal fins. The only new pigmentation is along the base of the first dorsal fin, where a row of small, close-set chromatophores is now evident.

A 12.0-mm. specimen (not figured) has characters similar to the 10.6-mm. specimen just described. The only differences are the presence of 3 chromatophores along the base of the second dorsal fin and 1 at the base of the second dorsal finlet. In addition to these pigmented areas, a slightly larger specimen of 13.4 mm. (not figured) has 3 small chromatophores along the margin of the anterior half of the upper jaw. Staining both specimens with alizarin disclosed 20 + 17 = 37 vertebrae, and fin ray counts of 15 spines, 11 rays, and 8 finlets in the dorsal and 11 rays and 8 finlets in the anal. The general body shape of these larvae resembles that of the 18.6-mm. specimen shown in figure 6.

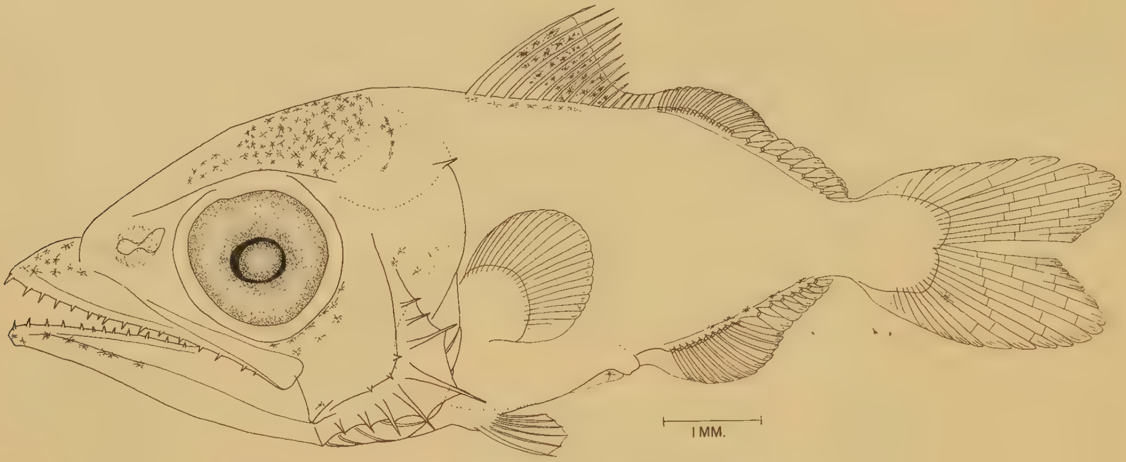

Figure 5. *Euthynnus lineatus*, 10.6 mm.

In addition to these changes, there is yet another which, while it has no significance in specific identification, may be of general biological interest. The naris, which on smaller specimens is represented by a single, ovate, indented nasal spot, gradually becomes more elongate with growth of the larva, and at some point between the 10.6-mm. and 12.0-mm. specimens it divides into two separate nares, a small, circular, anterior naris and a larger, somewhat elliptical, posterior one.

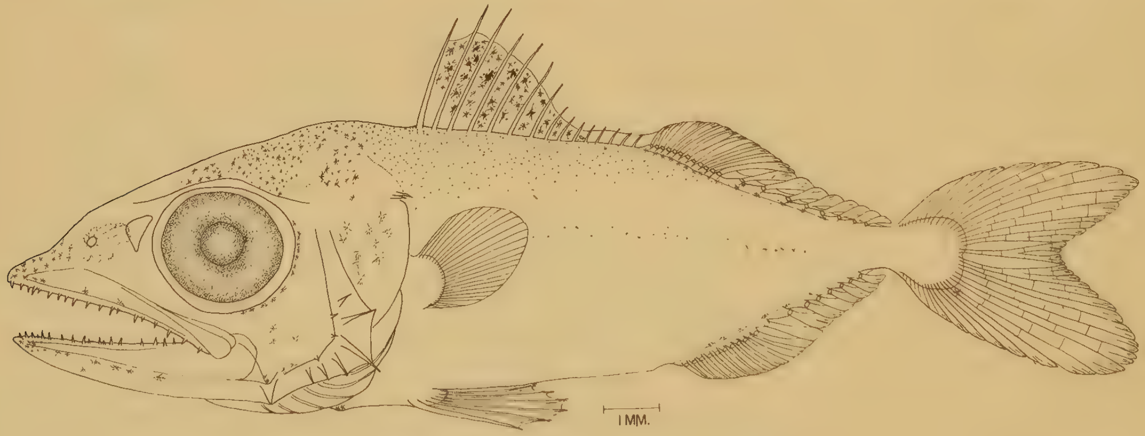

Figure 6. *Euthynnus lineatus*, 18.6 mm.

The specimen depicted in figure 6 is quite similar to the larger juveniles in body form. This is due mostly to a gradual reduction in the head depth relative to the body length and to the elongation of the abdominal sac, so that the anal opening is closer to the anal fin origin. Other changes, though not quite as prominent, can be seen in the more forward termination of the posterior margin of the upper jaw. In smaller specimens the end of the maxillary extends beyond a vertical through the posterior margin of the pupil. On the 18.6-mm. specimen, however, the end of the maxillary does not quite reach the vertical through the posterior margin of the pupil.

On the 18.6-mm. specimen the fins and finlets are more clearly defined. The dorsal fins consist of the full adult complement of 15 spines and 12 rays, followed by 8 finlets, whose tips are freee from each other. The bases of the finlets, however, are still connected by a membrane. The anal fin, consisting of 12 rays, is followed by 7 finlets which are developed similarly to their dorsal counterparts. The caudal fin is well developed and more deeply forked, and the pelvic fins are longer. The pectorals, with 24 completely formed rays, are comparable to the fully developed fins (24 to 26 rays) of the adults.

Further additions in pigmentation are noted on this specimen. The dorsal part of the body has a wide band of chromatophores which tapers posteriorly to the base of the fifth dorsal finlet. A row of small chromatophores is also present along the midlateral line of the body. These chromatophores extend from the tip of the pectoral fin to a vertical through the base of the fourth dorsal finlet. The series of chromatophores along the bases of the anal fin and finlets and also along the lower jaw remains relatively unchanged. Two widely separated chromatophores are seen near the middle of the upper jaw, and the snout, forebrain, midbrain and the surface of the opercle posterior to the eye show increased pigmentation. All the pigmented areas, except along the lower jaw, have extended rather rapidly, as can be seen on the 21.0-mm. specimen (fig. 7).

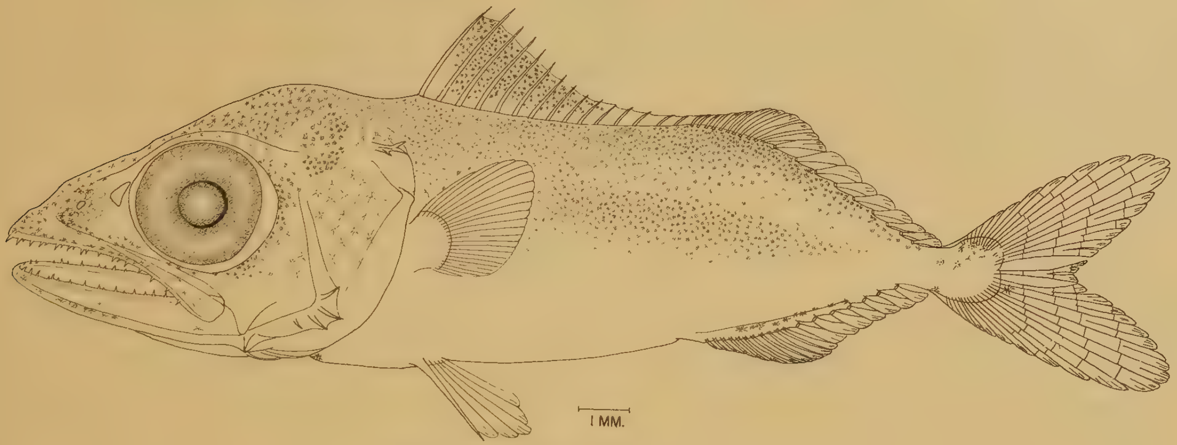

Figure 7. *Euthynnus lineatus*, 21.0 mm.

A 27.0-mm. specimen stained in alizarin has vertebral and fin ray counts identical with the 18.6-mm. specimen, and the external appearance of this specimen is an exact duplicate of the 21.0-mm. specimen described above.

Euthynnus alletteratus (Rafinesque)

Our description of this species is based on 68 specimens, ranging in sizes from 4.6 mm. to 18.0 mm. in total length, taken mainly by Danish vessels from the Atlantic Ocean and the Gulf of Mexico. Included in the total figure are 19 specimens obtained by the United States Fish and Wildlife Service vessel *Oregon* in the Gulf of Mexico. Although specimens smaller than 4.6 mm. are present in the catches, they are not included in the figure because species identification was not positive.

The general body shape of the 4.6-mm. specimen resembles that of the 5.5-mm. specimen shown in figure 8. In the former, there is no visible indication of spine or ray development in the unpaired fins. Instead, the fins are represented by a continuous membrane which starts in the region of the nape and extends around the caudal end of the body to the anal opening. The body contains 40 myomeres including the urostyle; the urostyle itself is undeveloped and extends posteriorly in line with the longitudinal axis of the body.

Chromatophores are present at the symphysis of the pectoral girdle and along the midventral line immediately anterior to the anal opening. The head is fairly well pigmented, with about 3 chromatophores over the forebrain and about 12 over the midbrain. A row of 3 or 4 well-spaced chromatophores is already evident over the middle two-thirds of the length of the lower jaw. About 11 are more or less evenly spaced along the midventral line in the posterior half of the body.

The 5.5-mm. specimen (fig. 8) shows some changes, the most distinctive being the development of 4 very short spines in the first dorsal fin. The second dorsal, anal, and caudal fins are beginning to develop, and the urostyle has turned upward. The chromatophores along the margin of the lower jaw have increased in number, and they extend over the anterior two-thirds of the jaw length. There are 9 chromatophores on the midventral line from the anal fin origin to the caudal peduncle. Each ramus of the upper and lower jaws bears about 14 teeth.

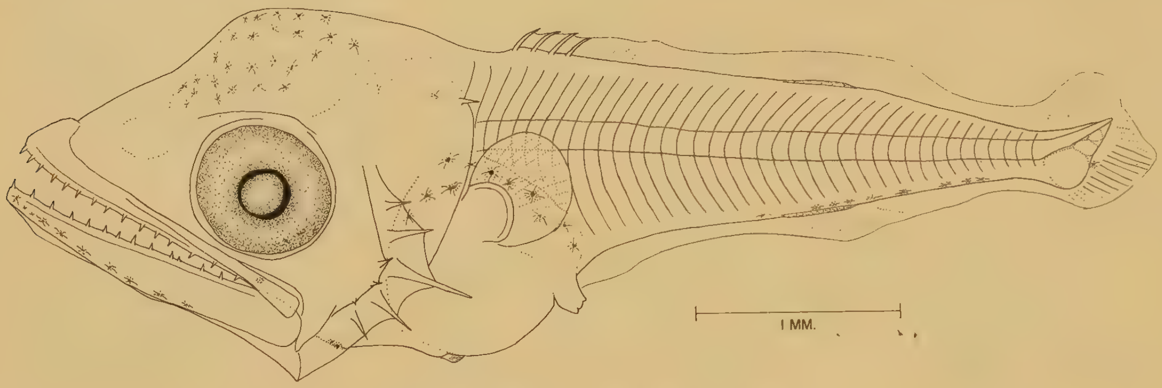

Figure 8. *Euthynnus alletteratus*, 5.5 mm.

Evidently the species undergoes very rapid changes at this stage of development, for a 7.5-mm. specimen (fig. 9) has 9 very long spines in the first dorsal fin, compared with only 6 spines on a 6.5-mm. specimen. Other fins are also well developed, with 12 or 13 rays in the second dorsal, 14 rays in the anal, and about 17 rays in the caudal fin. Although it is difficult to distinguish each ray, the basal elements or pterygiophores are clearly formed and can be counted accurately. Each ramus of the upper and lower jaws contains about 16 teeth. There are about 40 myomeres in the body.

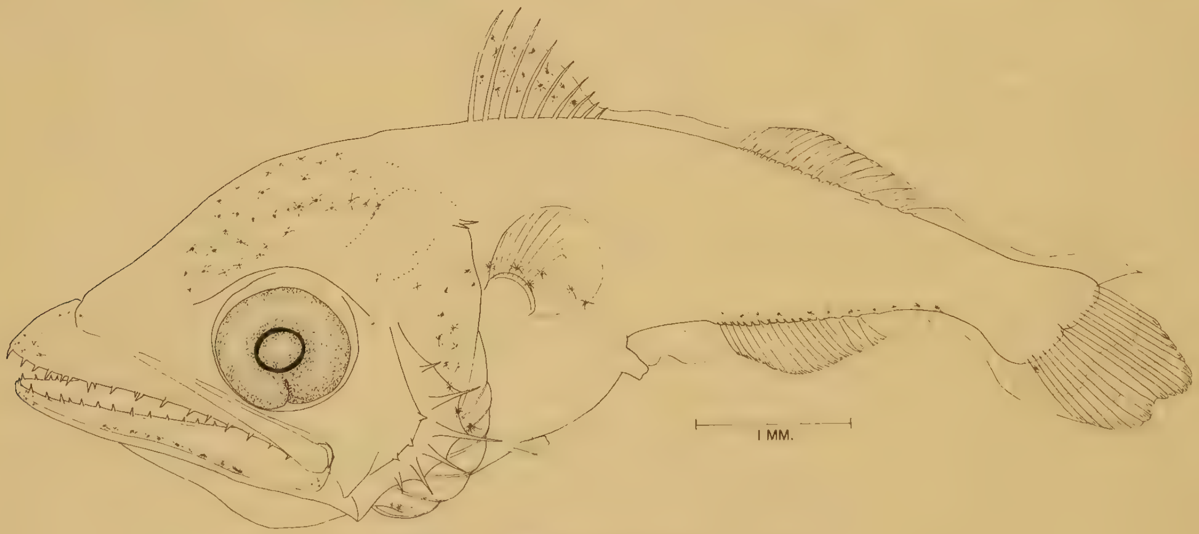

Figure 9. *Euthynnus alletteratus*, 7.5 mm.

A marked increase in pigmentation is noted on the first dorsal fin. About 13 well scattered chromatophores are present on the outer two-thirds of the fin between the first and seventh spines. The chromatophores along the lower jaw have increased in number, and they now appear closer together. Seven chromatophores are present over the forebrain, and 25 over the midbrain. The row of pigmentation along the midventral edge of the body consists of about 11 regularly spaced chromatophores. On some specimens there are as many as 15 chromatophores. In addition to these, several small chromatophores are present at the tips of the snout and lower jaw.

Perhaps the greatest development on the 9.3-mm. specimen (fig. 10) is the extremely long spines in the first dorsal fin. As in *lineatus* of comparable size, the length of the longest spine almost equals the body depth measured at the origin of the second dorsal fin. Both the second dorsal and anal fins have 13 rays, the pterygiophores of which are clearly visible. Similarly, the pterygiophores of the dorsal and anal finlets are clearly noticeable. The caudal fin rays are well developed, and the posterior edge of the fin now shows signs of becoming forked. The pectoral fins consist of about 9 completely formed rays, and the ventral fins, which were present on the 5.5-mm. specimen as small fleshy buds, are beginning to enlarge with the development of a definite outer spine.

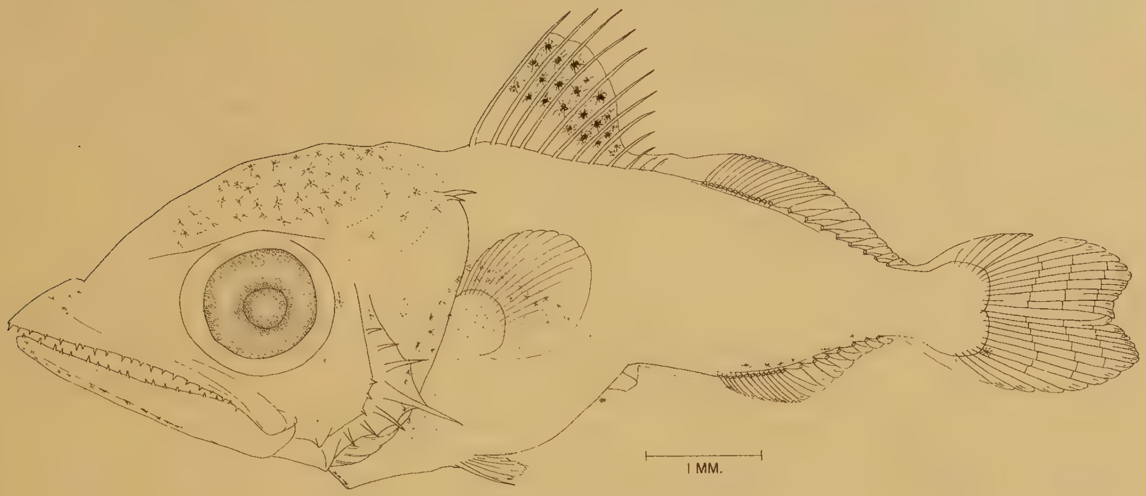

Figure 10. *Euthynnus alletteratus*, 9.3 mm.

Pigmentation on the first dorsal fin is restricted to the outer half of the fin membrane, but the number of chromatophores has increased to 22 and they extend over 8 interspinous membranes. An increase in pigmentation over the midbrain is also noted, and 4 light, well-spaced chromatophores are evident on the side of the head posterior to the eye. The rest of the head pigmentation appears unchanged from the previous specimen. The series of chromatophores along the midventral line shows some variation, and on this specimen only 6 chromatophores are present; 4 located along the posterior part of the anal fin base and 2 evenly spaced chromatophores located at the bases of the fourth and sixth anal finlets. Each ramus of the upper jaw now bears 20 teeth, and that of the lower jaw has 18; the number of myomeres is identical with that of the previous specimens.

Many changes are noted on the 10.6-mm. and 11.5-mm. specimens (not figured). Both of these have completely developed dorsal and anal fins, consisting of 16 spines and 13 rays in the dorsal followed by 8 finlets, and 14 rays in the anal followed by 7 finlets. The caudal fin is more clearly forked, and the pelvic fins have increased in length. The myomere count on the unstained 10.6-mm. specimen remains the same as on the previously described specimens, and the 11.5-mm. stained specimen has 20 + 19 vertebrae. The stained specimen also has 21 or 22 teeth and 23 or 24 teeth on each ramus of the upper and lower jaw, respectively.

The increase in pigmentation is evident in several places. The margin of the lower jaw bears two rows of chromatophores and the upper jaw has a single row of chromatophores along two-thirds of its length. The larger of the 2 specimens has a third row of chromatophores along the anterior half of the lower jaw. About 4 or 5 closely grouped chromatophores are seen at the angle of the jaws, and about 8 large chromatophores are present on the surface of the opercle posterior to the eye. A band of pigment, about 4 chromatophores wide, is seen along the dorsal edge of the body. This band tapers to a single row of chromatophores at about the twelfth dorsal spine and continues to the origin of the second dorsal finlet. The first sign of pigmentation, 1 or 2 chromatophores along the midlateral line of the body, is seen between verticals through the

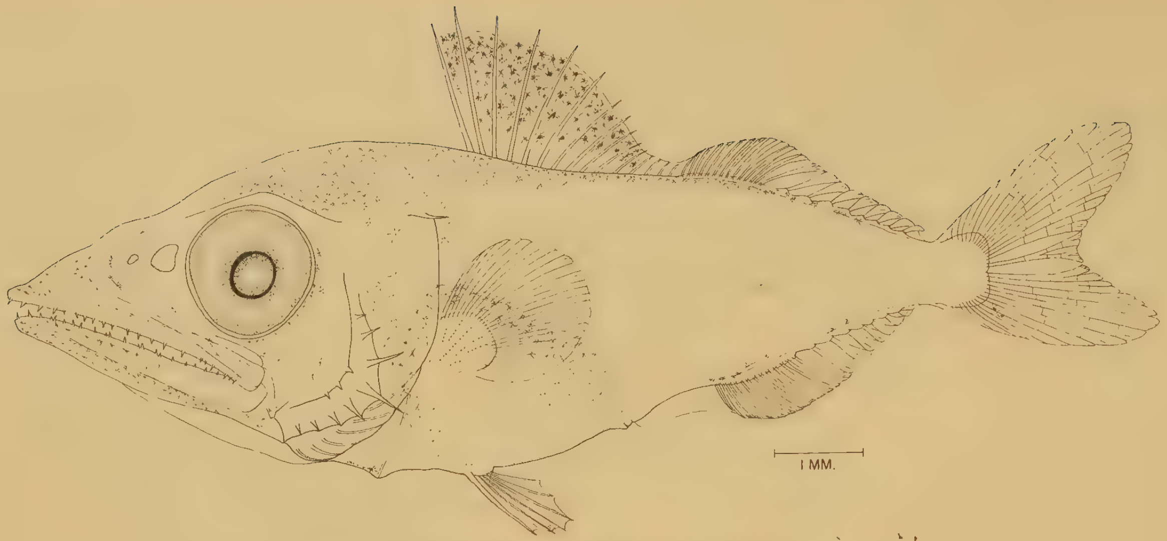

Figure 11. *Euthynnus alletteratus*, 12.0 mm.

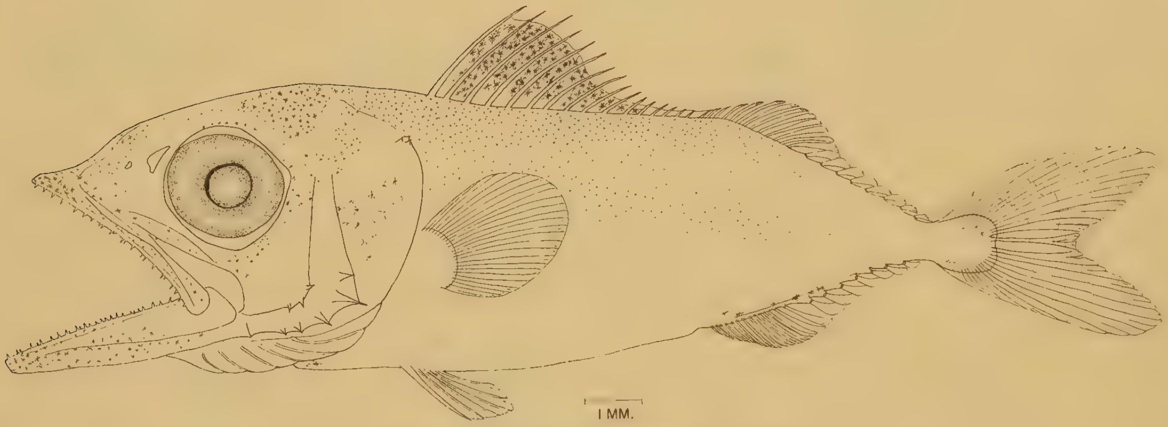

Figure 12. *Euthynnus alletteratus*, 18.5 mm.

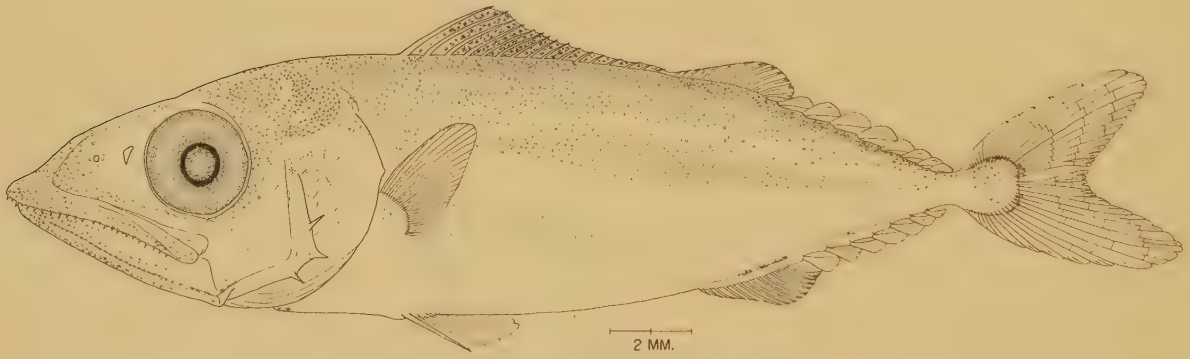

Figure 13. *Euthynnus alletteratus*, 26.0 mm.

anterior and posterior end of the second dorsal fin. About 10 chromatophores are present along the bases of the anal fin and the first 4 anal finlets.

The characteristics noted above can be seen in the 12.0-mm. specimen shown in figure 11. Between this example and the 18.5-mm. specimen (fig. 12), the changes are quite distinctive. The shape of the body is more like that of the larger juveniles due to the elongation of the abdominal sac and the more posterior placement of the anus. The head parts, especially the mouth, appear smaller with respect to the total length of the body, and the fins and finlets are more clearly defined.

There is an increase in pigmentation over the head and dorsal half of the body, and the band of chromatophores along the midlateral line of the body is especially obvious.

Except for the first dorsal fin, the outline of which resembles that of the adult fin, and the narrower body relative to total length, there is very little difference between the 18.5-mm. specimen and the 26.0-mm. specimen of figure 13. The only perceptible change on specimens greater than 26.0 mm. is in the increase of pigmentation on the body. However, the change is so gradual that it is not evident until about 40 mm., when 1 to 3 very faint spots or vertical bars are seen along the dorsal third of the body. These bars increase in number to about 10 on a 58.0-mm. specimen (fig. 14), and to 13 on a 94.3-mm. specimen; the largest one examined in our collection. Superficially, at least, these larger specimens resemble the juveniles of *yaito* of WADE (1950). However, the 58.0-mm. specimen and others ranging in sizes from 40 to 94.3 mm. have total gill raker counts of 33 or more, with 25 to 28 on the lower limb of the arch. The *yaito* examined by WADE, on the other hand, had total gill raker counts of 30 to 32, with 22 to 23 on the lower limb, even though these were much larger specimens (127—175 mm.).

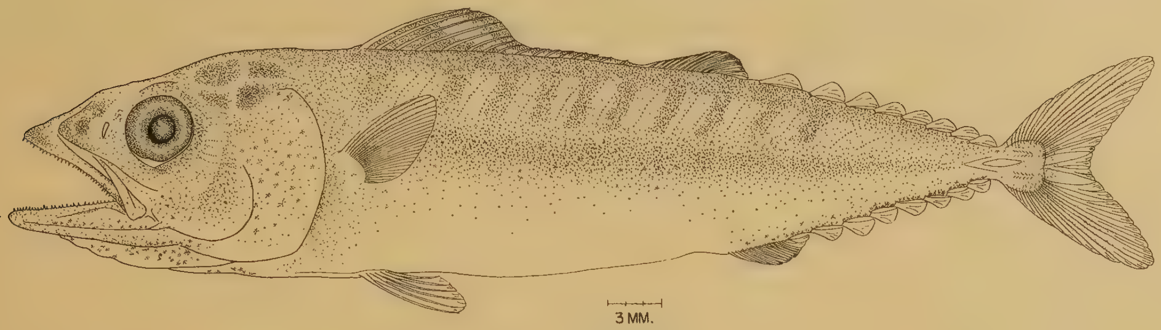

Figure 14. *Euthynnus alletteratus*, 58.0 mm.

All seven juveniles (25 mm., 30 mm., 30 mm., 40 mm., 45 mm., 63 mm., and 63 mm.) which were stained in alizarin have 20 precaudal and 19 caudal vertebrae, including the urostyle.

Euthynnus yaito KISHINOUYE

The study of this species is based on examination of 238 larvae and postlarvae taken mainly from the East Indies waters. A detailed description of this species, based on about 100 of the specimens mentioned above, is given in a previous publication (MATSUMOTO, 1958a). Although the species was only tentatively set as *yaito* in that paper, examination of additional material, including those of other species described in the previous sections, shows that the earlier identification is largely correct. In order to avoid needless repetition of the previous publication, only 4 characters, those most useful in separating *yaito* from other species, are discussed, and several of the previously used illustrations of *yaito* are reproduced here.

The first character we should like to review is the pigmentation of the lower jaw. Generally, a single chromatophore is present at the middle of the lower jaw in the smaller specimens. This is seen clearly in the 4.6-mm. specimen (fig. 15). The number of chromatophores increases to about 3 on a 7.6-mm. specimen (fig. 16), and to 4 or 5 on a 9.6-mm. specimen (fig. 17). These chromatophores are well separated from each other and are generally located in the anterior one-half to two-thirds of the lower jaw. Evidently this pigmentation increases slowly, for a 12.2-mm. specimen (not figured) has only 8 chromatophores over the entire length of the lower jaw.

The second character is the pigmentation along the ventral edge of the body near the caudal region. Five chromatophores are seen on the 4.6-mm. and 7.6-mm. specimens, whereas only 3 chromatophores appear on the 5.5-mm. specimen (not figured) and on the 9.6-mm. specimen. A 12.2-mm. specimen shows 4 chromatophores. Thus, although there is some variation in the number of chromatophores along the ventral edge of the body, it does not seem to be related to the size of the specimen. On the 12.2-mm. specimen,

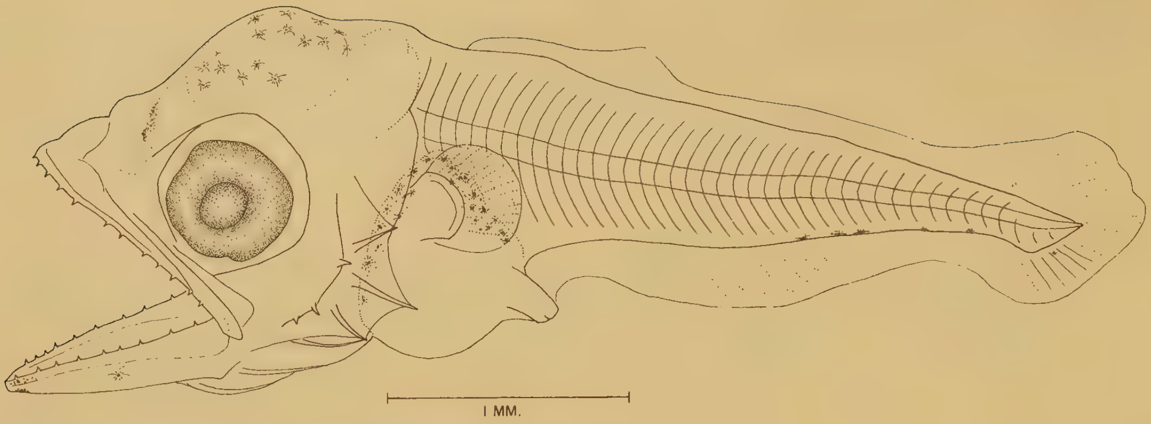

Figure 15. *Euthynnus yaito*, 4.6 mm.

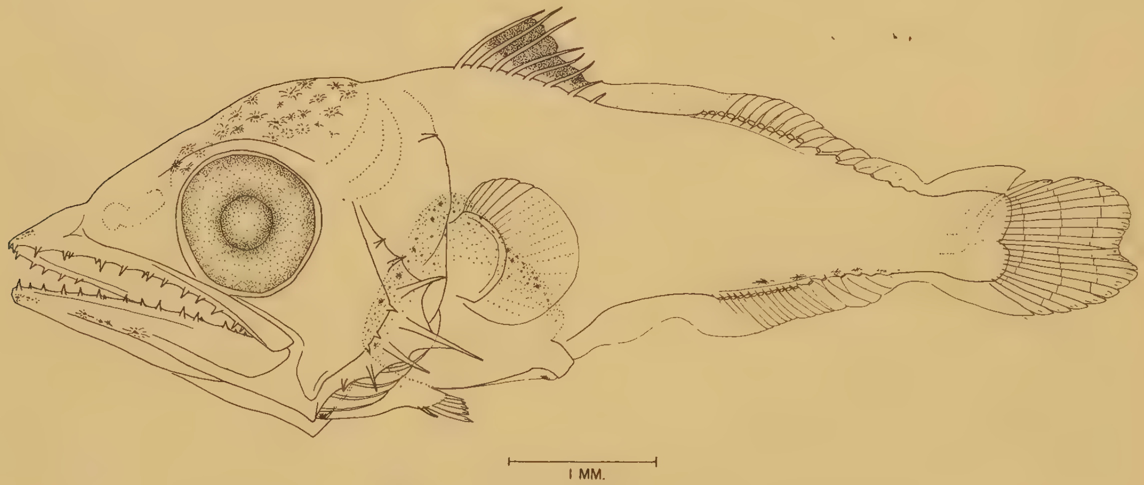

Figure 16. *Euthynnus yaito*, 7.6 mm.

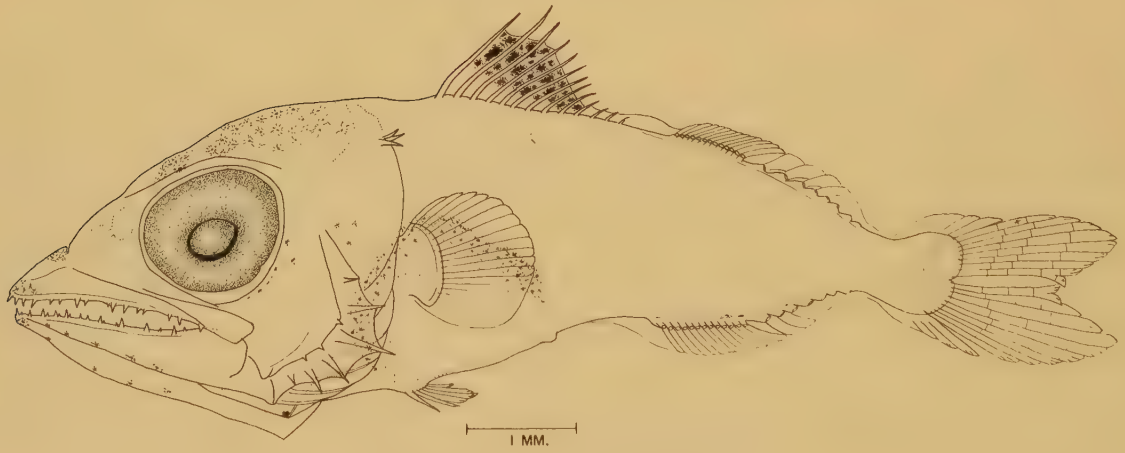

Figure 17. *Euthynnus yaito*, 9.6 mm.

4 additional chromatophores are present along the bases of the posterior end of the second dorsal fin and the first 3 dorsal finlets. These chromatophores are not yet developed on specimens below this size.

The third character is the number of myomeres or vertebrae. On all specimens below 8.0 mm. the myomere count is either 40 or 41. This compares well with the number of vertebrae ($20+19=39$) found on stained specimens larger than 9.6 mm.

Finally, the larger specimens, 9.6 mm. and 12.2 mm., have 13 or more rays in both the second dorsal and anal fins.

Discussion of Species Differences.

The foregoing descriptions include certain consistent characters by which the three species of *Euthynnus* may be separated. Specimens larger than 9 or 10 mm. already show the adult complement of vertebrae. Using this character, it is possible to separate *lineatus*, which has 20 + 17 = 37 vertebrae, from both *yaito* and *alletteratus*, which have 20 + 19 = 39. Moreover, the number of rays in the second dorsal and anal fins of *lineatus* is consistently lower than in the other two species; *E. lineatus* normally has 11 or 12 rays in each fin, whereas *yaito* and *alletteratus* usually have 13 rays in the second dorsal and 13 or 14 rays in the anal fin. The separation of *lineatus* from the other two species is further aided by the fact that this species has been reported only from the Pacific Ocean off the western coast of North and Central America.

It would be easier to separate *alletteratus* from *yaito*, if the gill rakers were completely formed on juveniles and larvae. Since specimens smaller than 50 mm. do not have the full adult count, the separation of individuals below this size must be based on other criteria.

As far as is known, no adult *yaito* has ever been reported from the Atlantic Ocean and its adjoining bodies of water. *E. lineatus* is also not a possibility here, since this species has been reported only from the eastern Pacific. Therefore any *Euthynnus* larvae or juveniles taken from these waters are likely to be *alletteratus*. This supposition is supported by the extent of pigmentation on the head of the young. Our samples of *alletteratus* below 50 mm. are more heavily pigmented along the length of the upper and lower jaws than *yaito* of the same size.

In specimens smaller than 9 or 10 mm., the identifying characters are generally limited to body pigmentation. This does not mean, however, that the pigmentation peculiar to each species is restricted to this size group alone. On the contrary, these differences persist through specimens in the 25-mm. to 30-mm. group. Specifically, specimens of *yaito* and *lineatus* consistently bear fewer chromatophores along the lower jaw than comparable specimens of *alletteratus*. In *yaito* the lower jaw of the smallest specimen (4.6 mm.) has only 1 chromatophore, exclusive of those at the tip. The number of chromatophores increases to 5 in a 9.6-mm. specimen, and to about 8 in a 12.2-mm. specimen. In *lineatus*, the smallest specimen (5.0 mm.) has no chromatophores on the lower jaw. Between the 6.0-mm. and 21.0-mm. specimens the number of chromatophores increases from 3 to 8. For comparison, the smallest *alletteratus* examined (4.6 mm.) possesses 3 to 4 chromatophores on the lower jaw, and specimens between 5.5 mm. and 9.3 mm. have about 7 to 10 chromatophores which extend over nearly four-fifths the length of the lower jaw. A more striking difference is seen on the 12.0-mm. specimen, which has 2 rows of about 20 chromatophores in each row.

Another difference in pigmentation is seen in the row of chromatophores along the ventral margin of the body in the region of the anal fin and finlets. *E. yaito* and *lineatus* have 3 to 5 chromatophores, whereas *alletteratus* has from 6 to 11.

Despite the similarity in body pigmentation between *lineatus* and *yaito*, these two species can be separated by another character. The former species has either 38 or 39 myomeres, whereas the latter, as well as *alletteratus*, has 40 or 41.

It is interesting to note that in *Euthynnus* there are rarely any chromatophores along the midlateral and middorsal lines of the caudal peduncle. The only indication of such pigmentation occurs in specimens larger than 12 mm. in the case of *alletteratus*, and in specimens larger than 18.6 mm. in the case of *lineatus*. The largest *yaito* examined (12.2 mm.) does not show any pigmentation in these areas. Although these characters have no bearing on the separation of the *Euthynnus* species, they must be considered, not only because they are important in differentiating this genus from *Auxis*, but because our descriptions of *Euthynnus* differ from the previously published reports of Ehrenbaum (1924) and Wade (1949).

Ehrenbaum (1924) separates *Euthynnus* from *Auxis* mainly on the appearance of the first dorsal fin. He states that in *Auxis* the fin membrane posterior to the ninth ray (spine) becomes lower and is usually gone in specimens of 11 mm. to 12 mm. in length; and that in *Euthynnus* it (the fin membrane) continues at a similar height to the second dorsal, and, when stained, 6 very obscure rays seem to appear on it, thus bringing the total rays to 15.

Examination of the specimens at hand shows that the fin membrane between the last spine of the first dorsal and the origin of the second dorsal fin is still present on a 15.5-mm. *Auxis*, and that the height of the fin membrane varies widely among specimens of the same species. It is believed that the variation in this character is mainly an artifact caused by preservation and is unreliable in separating the larvae of these two species.

Ehrenbaum's separation of *Euthynnus* based on the number of spines in the first dorsal fin seems to be in error. The "6 very obscure rays" which he mentions in describing *Euthynnus* are clearly noticeable on our specimens of *Auxis* measuring between 9.7 mm. and 50.0 mm. These rays or spines are most prominent on specimens measuring between 11 mm. and 15 mm., and they gradually become inbedded beneath the outer layer of skin in larger juveniles. Schaefer and Marr (1948) also noticed these subcutaneous spines on their juvenile *Auxis*.

Further observations on the number of first dorsal spines relative to body length of the two species also add to the doubt of Ehrenbaum's separation. The dorsal fin spine count of Ehrenbaum's *alletteratus* differs from that of our 3 species of *Euthynnus*. In his figures of *alletteratus*, he shows 6 spines in the first dorsal fin of an 8.6-mm. specimen, and about 9 spines in a 10.1-mm. specimen. In our material, however, the 3 species of *Euthynnus* between 7 mm. and 8 mm. already have 7 to 9 spines, and specimens between 9 mm. and 10 mm. have 12 to 15 spines. All our specimens above 10 mm. have 15 to 16 spines, which corresponds to the total count of the adult *Euthynnus*. Ehrenbaum's lower counts, on the other hand, agree with our counts on *Auxis*. Our *Auxis* larvae between 7 mm. and 8 mm. in length have 6 to 8 spines in the first dorsal fin, and those between 9 mm. and 11 mm. have 9 spines, only 1 or 2 spines less than the full adult complement. The latter count of 9 spines is identical with Ehrenbaum's 10.1-mm. specimen, which he designates as *E. alletteratus*.

Differences in pigmentation are also noticeable. Ehrenbaum reports that *Euthynnus* has 1 to 3 chromatophores along the bases of the anal finlets and sometimes a single chromatophore at the base of the last dorsal finlet. In the present study the specimens designated as *Euthynnus* in no case bear any chromatophore at the base of the last dorsal finlet. On the contrary, this pigmentation normally appears on specimens having fewer spines in the first dorsal fin, that is, on specimens designated here as *Auxis*. Furthermore, Ehrenbaum's descriptions of *Euthynnus* give no indication of pigmentation on the first dorsal fin. In contrast with this, our specimens show very noticeable pigmentation on this fin as early as 7.1 mm., and the entire fin is completely pigmented at 12 mm. This pigmentation persists even on specimens as large as the 58-mm. *alletteratus* figured here (fig. 14). Schaefer and Marr's (1948) descriptions of juvenile *lineatus* and Wade's (1950) descriptions of juvenile *yaito* also show the first dorsal fin as being heavily pigmented.

Wade (1951) describes the larvae of *yaito* as having 3 distinct rows of chromatophores in the region of the caudal peduncle, and like Ehrenbaum's description, his illustration of the 10.5-mm. specimen shows only 8 spines in the first dorsal fin. In contrast with this, our *yaito* at 9.6 mm. has 13 spines in the first dorsal fin, and the chromatophores in the caudal region are present only along the midventral line of the body.

On the basis of these observations the author believes that the larval *Euthynnus* of Ehrenbaum (1924) and of Wade (1951) should be designated as *Auxis*.

GENUS *AUXIS*

Notes on Adults and Juveniles.

It is generally accepted that there are two forms of *Auxis*. These can be separated from each other mainly by a difference in corselet development. The corselet is a plaque of scales on the anterior part of the body in the form of 3 wedges, whose apices point posteriorly (fig. 18). The dorsal wedge begins near the tip of the pectoral fin, halfway between the lateral line and the dorsal edge of the body. The outline trails poseriorly, rising toward the origin of the second dorsal fin. From the anterior end of the dorsal wedge, the lorsal profile of the middle extension of the corselet trails posteriorly and ventrally toward the lateral line nd meets its complement which begins near the angle of the opercle and rises obliquely toward the lateral ine. The lower wedge begins near the angle of the opercle and trails ventrally toward the tip of the ventral ins. Variations in the length of the corselet occur only in the middle branch which roughly follows the ateral line; hence the term corselet as used in this paper shall refer to this middle extension.

One form of *Auxis*, specifically known as *thazard* (Lacépède, 1802), is characterized by a short corselet vhich narrows abruptly a little past the tip of the pectoral fin and extends posteriorly only to about midway etween the origins of the first and second dorsal fins. At the level of the second dorsal origin, the corselet usually is only one scale-row wide. The second form of *Auxis* is characterized by a long, gradually tapering corselet which extends to, and in many instances goes beyond, the base of the second dorsal finlet. The corselet s 9 to 18 scale-rows wide below the origin of the second lorsal fin on specimens 195 mm. to 200 mm. in total ength.

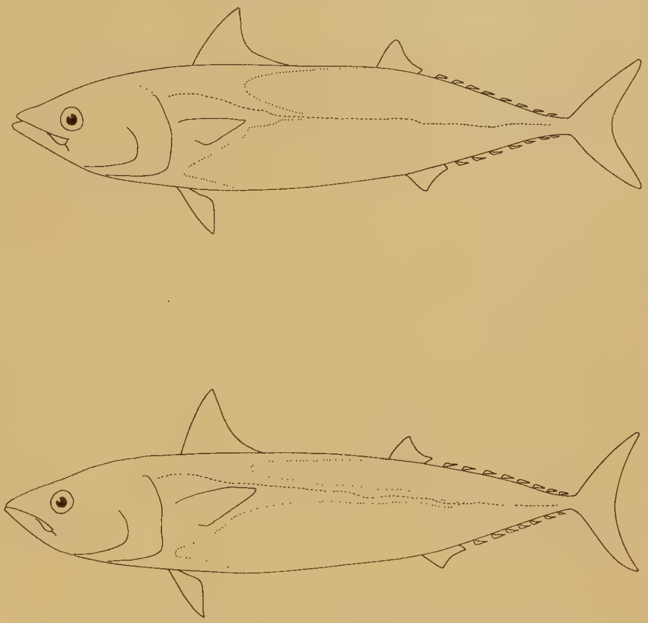

Figure 18. Sketch of *Auxis* showing corselet formation.

The nomenclature of the long-corseletted form is ather confused. For many years, the name *tapeinosoma* Bleeker was ascribed to such specimens taken in the Philippine waters. After studying Bleeker's (1854) lescription of *tapeinosoma*, the author has come to the conclusion that this is not the long-corseletted form. Bleeker describes *tapeinosoma* as having a corselet which "ends slightly posterior to the pectoral fins". Most of the other characters he mentions agree more closely with specimens of *thazard*, than they do with specimens of the Philippine long-corseletted form. Furthermore, through correspondence with John E. Fitch, California Department of Fish and Game, who examined the type specimen of *tapeinosoma*, the author learned that Bleeker's fish is definitely the short-corseletted form. Bleeker's (1855) description of a specimen from Ternate, East Indies, which he named *A. thynnoides*, seems to be the long-corseletted form. He describes this fish as having a corselet which "ends far behind the pectoral fin". Thus, the long-corseletted *tapeinosoma* of Wade (1949) and of Herre and Herald (1951) appears to be a misnomer and will be called *A. thynnoides* Bleeker in this paper.

In addition to the differences in corselet breadth and length, Wade (1949) and Herre and Herald (1951) point out that *thazard* in the western Pacific normally has fewer gill rakers than *thynnoides* (see table 3). Mead (1951) also mentions the low gill raker counts on the eastern Pacific *thazard* taken off the coast of Central America. Godsil (1954), however, reports that his *thazard* (all of which definitely possessed the short corselet), which were taken off Baja California and the Galapagos Islands, have high gill raker counts similar to those of *thynnoides* described by Wade (1949) and Herre and Herald (1951). It therefore appears as though the number of gill rakers, by itself, may not be a reliable character in differentiating the two forms of *Auxis*.

The distribution of the two forms of *Auxis* in the Atlantic is also in a confused state with contradictory views being held by various investigators. Herre and Herald (1951), who are aware of the differences between *thazard* and *thynnoides*, recognized Atlantic *thazard*, but Fitch (private correspondence), who has also examined Atlantic *Auxis*, is of the opinion that no *thazard* occurs there, and that the Atlantic form is not separable from the western Pacific long-corseletted form. The author has examined a 287-mm. specimen of *Auxis* from Woods Hole, Massachusetts, which is presently deposited in the United States National Museum. This specimen has the long corselet typical of *thynnoides*. A review of the literature shows that

Table 3. Gill raker counts of *Auxis* obtained by various investigators.

	Number of gill rakers	*Auxis thazard*					*Auxis thynnoides*	
		Philippine[1]	Hawaii[2]	Central America[3]	Baja California[4]	Atlantic[5]	Philippine[1]	Hawaii[2]
Upper limb	7	3	–	2	–	–	2	–
	8	2	–	2	–	3	2	–
	9	77	–	3	–	12	5	–
	10	109	8	2	4	7	99	14
	11	1	2	–	1	–	103	6
	12	–	–	–	–	–	5	–
Angle of arch	1	212	10	9	4	22	216	20
Lower limb	27	4	–	1	–	–	–	–
	28	40	–	–	–	–	–	–
	29	74	1	3	–	–	–	–
	30	59	5	2	–	5	–	–
	31	28	2	2	1	4	1	–
	32	5	1	1	–	6	19	4
	33	–	1	–	3	6	53	2
	34	–	–	–	–	1	79	10
	35	–	–	–	1	–	42	2
	36	–	–	–	–	–	19	2
	37	–	–	–	–	–	3	–
Total gill rakers	36	–	–	1	–	–	–	–
	37	2	–	–	–	–	–	–
	38	17	–	1	–	–	–	–
	39	47	–	1	–	1	–	–
	40	66	5	2	–	2	–	–
	41	42	3	1	–	7	2	–
	42	32	1	1	1	3	2	–
	43	6	1	1	–	5	14	3
	44	–	–	1	2	4	40	2
	45	–	–	–	2	–	57	9
	46	–	–	–	–	–	51	3
	47	–	–	–	–	–	31	2
	48	–	–	–	–	–	13	1
	49	–	–	–	–	–	3	–
	50	–	–	–	–	–	3	–
Number of specimens		212	10	9	5	22	216	20

[1] Wade, 1949; Herre and Herald, 1951.
[2] Matsumoto, 1958b.
[3] Mead, 1951.
[4] Godsil, 1954.
[5] Herre and Herald, 1951.

most of the descriptions of *Auxis* from the Atlantic do not mention the corselet. Nearly all of these papers however, refer to the figure of *thazard* given by Jordan amd Evermann (1900), which definitely show the long corselet as in *thynnoides*. It is possible that Herre and Herald (1951) and Fitch (private correspondence) examined different forms of *Auxis*, and that the two types of *Auxis* may be present in the Atlantic

Two forms of *Auxis* were known to occur in both the eastern and western parts of the Pacific, but unti recently only one (*thazard*) was known from the central Pacific area. On November 30, 1957, 21 long-corseletted specimens were captured by pole-and-line fishing in the Hawaiian Islands from the United State Fish and Wildlife Service' research vessel, "John R. Manning". These specimens were found to be identica (Matsumoto, 1958b) with the Philippine long-corseletted form described by Wade (1949).

It is interesting to note that both long- and short-corseletted forms taken in Hawaiian waters were fro the same school. Through correspondence with Dr. S. Jones, Chief Research Officer at the Central Marin Fisheries Research Station, Mandapam Camp, South India, it was learned that two types of *Auxis* also occu in the Indian Ocean, and that they are frequently found together in the same school. Similar observation were also reported by Kishinouye (1915).

The separation of juveniles of these two forms imposes a difficult problem, since the most reliable character upon which the separation of the adults is accomplished (corslelet morphology) does not appear unt the fish are about 200 mm. in fork length. Gill raker counts are of limited aid also, since this character is only applicable to fish taken from certain localities where the two forms exhibit extreme counts.

The larvae, however, seem to show some variation in pigmentation, and because there is a possibility that this variation may be associated with the two forms of *Auxis*, two separate series of larvae are described in this study. These series are designated as types I and II, and the validity of their separation is discussed later in this report.

Descriptions of Larvae and Postlarvae.

The descriptions of *Auxis* are based on an examination of 2,195 specimens (1,425 type I; 770 type II) taken by various Danish vessels, principally the "Dana". Of this number 63 larval specimens from the Atlantic and 76 from the Pacific were studied in detail. In addition, 50 juveniles from the Gulf of Mexico ranging in length from 20 mm. to 84 mm. were examined and compared to Wade's collection of 21 *A. thazard* and 15 *A. thynnoides* between 40 mm. and 238 mm. from Philippine waters.

Auxis type I.

Type I is represented by a series of larvae which resembles the form described in a previous paper (Matsumoto, 1958a). It was stated then that the series belonged to the genus *Auxis* mainly on the basis of (1) two or more rows of chromatophores in the region of the caudal peduncle, (2) the pigmented spot at the symphysis of the pectoral girdle, (3) the relatively small number of spines (less than 9 or 10) in the first doral fin, and (4) the paucity of chromatophores in the first dorsal fin. The species was designated tentatively as *thazard*, inasmuch as many of the specimens were taken in Hawaiian waters, where adults of only *A. thazard* were then known to occur regularly. Part of the material used in that paper was taken on one of the "Dana" cruises, and most *Auxis* figures were drawn from these specimens. The original illustrations are reproduced here as figures 19 to 23.

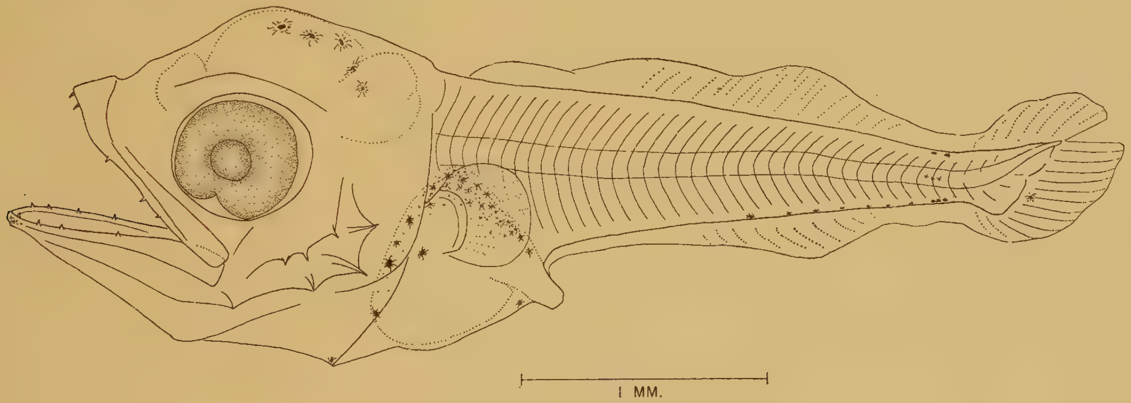

Figure 19. *Auxis* type I, 4.5 mm.

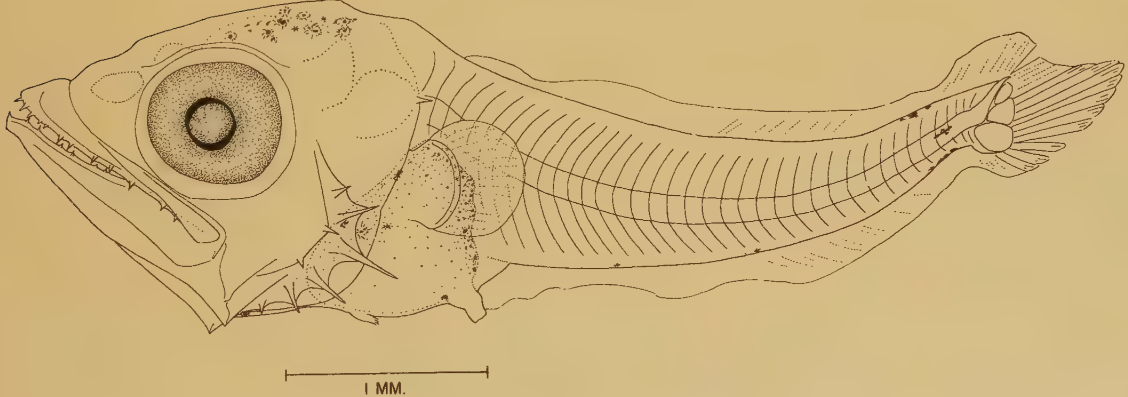

Figure 20. *Auxis* type I, 5.5 mm.

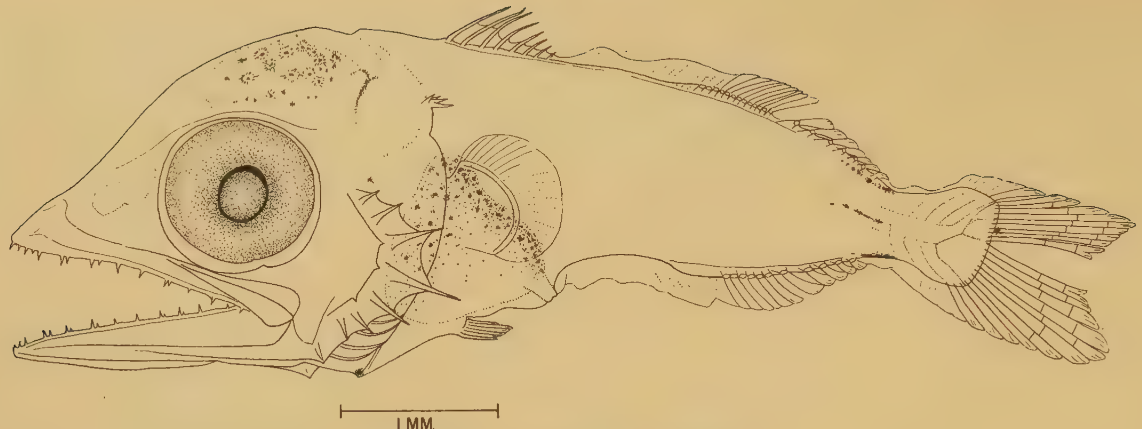

Figure 21. *Auxis* type I, 7.05 mm.

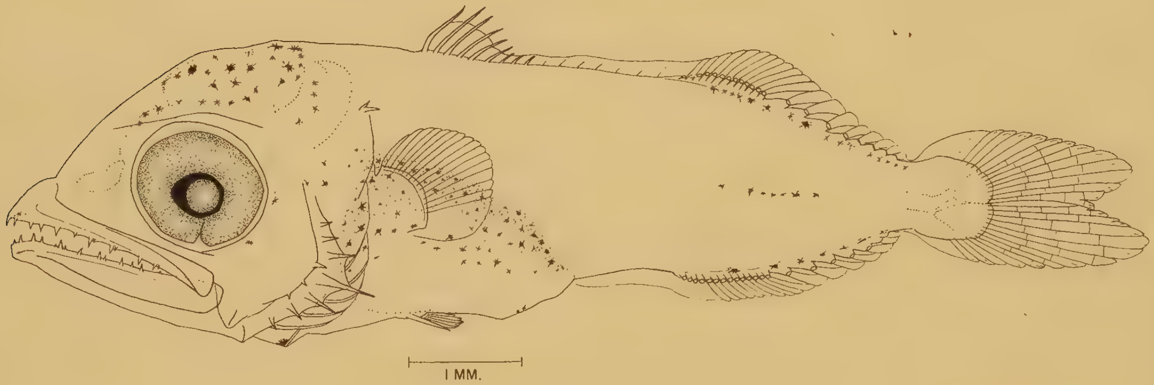

Figure 22. *Auxis* type I, 9.7 mm.

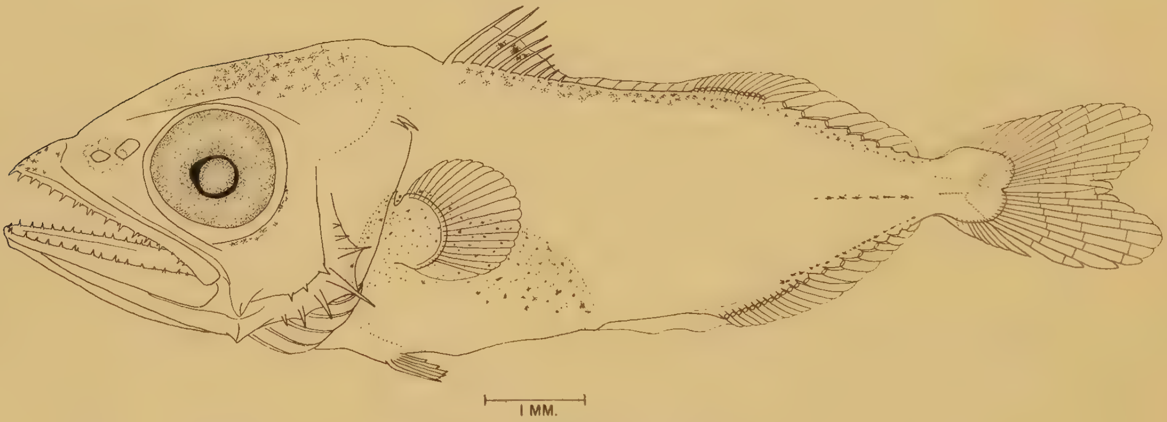

Figure 23. *Auxis* type I, 11.2 mm.

It is needless to repeat all the details of description for type I. Instead, a resumé of the more important characters mentioned above follows:

(1) *Two or more rows of chromatophores in the region of the caudal peduncle.* In this particular series, even the smallest specimen, 4.5 mm. (fig. 19), has 3 distinct rows of close-set chromatophores along the mid-dorsal, midlateral, and midventral lines of the caudal peduncle. The chromatophores increase in number with growth of the fish, and by the time the species has attained 11.2 mm. (fig. 23) 1 or 2 rows of chromatophores are present along the dorsal midline of the body from the origin of the first dorsal fin to the caudal peduncle. The number of chromatophores along the midlateral line also increases, and in a 13.2-mm. specimen (fig. 24) the chromatophores have moved internally toward the vertebral column. At about 14.0 mm. a single row of dermal chromatophores is seen along the midlateral line slightly posterior to the tip of the

pectoral fin. This row gradually increases in width and length until it appears as a wide, dark band, which is distinctly noticeable in the 25-mm. specimen (fig. 25).

(2) *Pigment spot at the symphysis of the pectoral girdle.* This spot, common to both *Auxis* and *Euthynnus*, is present in nearly all of the specimens examined. It usually consists of a single large chromatophore in specimens below 20 mm. In larger specimens, however, this spot may be represented by 2 to 4 small, closely grouped chromatophores.

(3) *Number of spines (less than 9 or 10) in the first dorsal fin.* The first dorsal spines are insufficiently developed for comparative purposes in specimens below 7 or 8 mm. The 9.7-mm. specimen (fig. 22), however, possesses a first dorsal fin composed of 9 well-developed spines which closely resemble that of the adult. The first and second dorsal fins are widely spaced, and the initial development of 7 additional small spines are noticed between the end of the first and the origin of the second dorsal fins. These spines do not develop to any great length, as noticed in the 25-mm. specimens, but are still distinctly noticeable on larger juveniles up to about 50 mm. Except for the anterior 2 or 3 spines, which later develop as part of the first dorsal fin of the adult, these inter-dorsal spines ultimately become inbedded beneath the outer layer of skin.

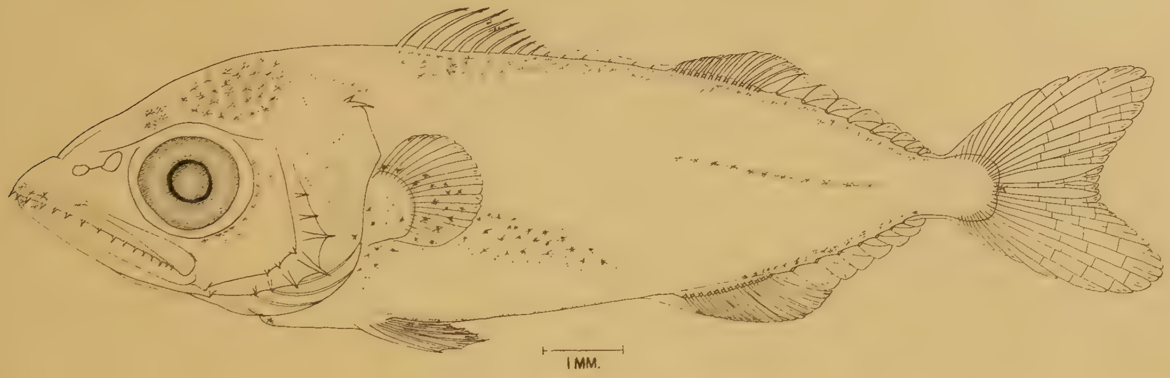

Figure 24. *Auxis* type I, 13.2 mm.

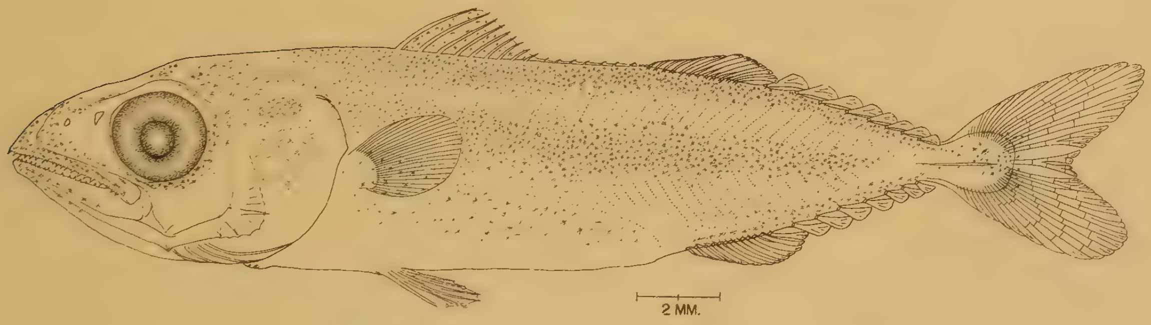

Figure 25. *Auxis* type I, 25.0 mm.

(4) *Number of chromatophores in the first dorsal fin.* Generally, the first dorsal fin of juvenile *Auxis* in very lightly pigmented and is almost colorless. The first signs of pigmentation on this fin appear rather late, at about 11.0 mm., and the 11.2-mm. specimen illustrated here has only 3 large chromatophores. The 13.2-mm. specimen also shows few chromatophores. Beyond this size the number of chromatophores seems to increase with growth, but at no stage is this pigmentation conspicuous. The chromatophores themselves are scattered almost evenly throughout the fin membrane, as shown in the 25.0-mm. specimen (fig. 25).

***Auxis* type II.**

Type II refers to a series of larvae, measuring from 3.5 mm. to 7.2 mm., which lack chromatophores along the midlateral line in the caudal peduncle region. This lack, however, is not always consistent, and on some specimens chromatophores are missing on one side only. The smallest specimen (fig. 26) has a single

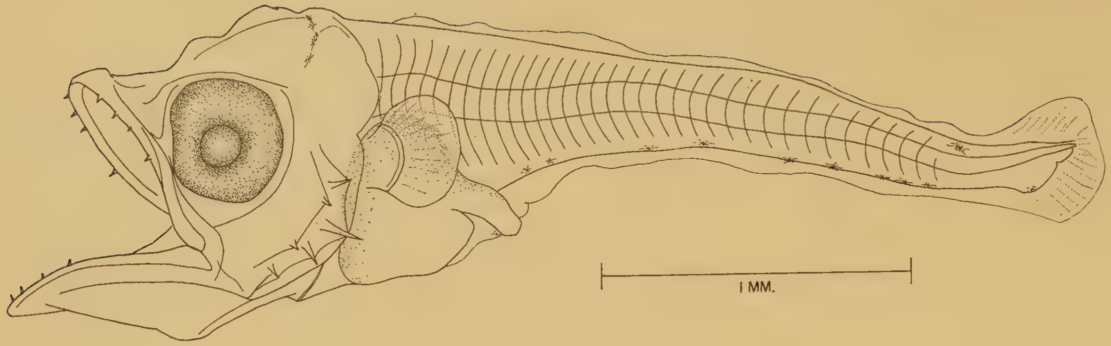

Figure 26. *Auxis* type II, 3.5 mm.

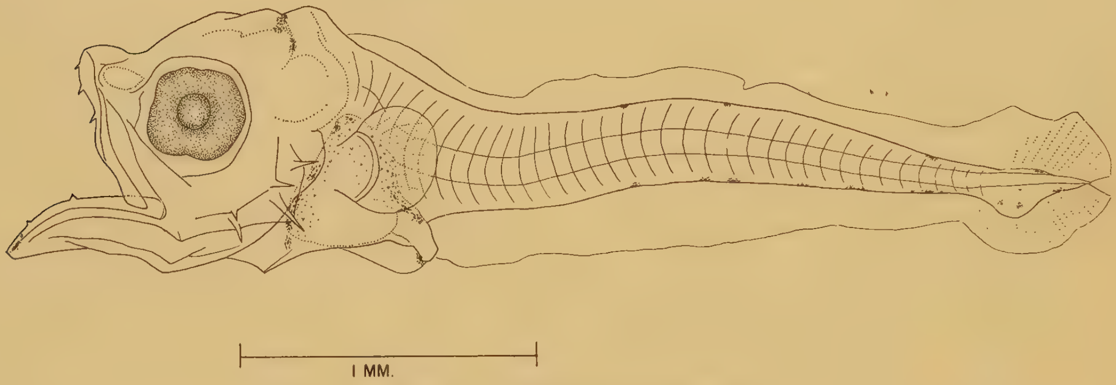

Figure 27. *Auxis* type II, 3.7 mm.

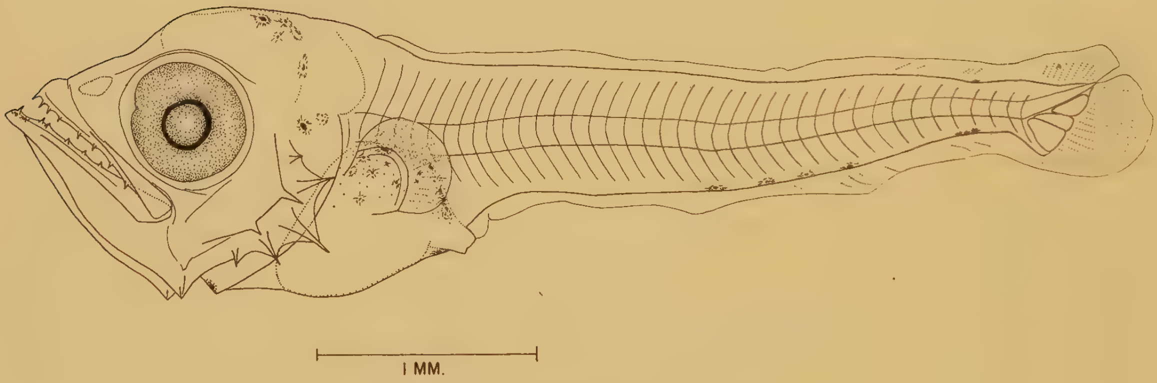

Figure 28. *Auxis* type II, 5.2 mm.

darkly pigmented spot at the symphysis of the pectoral girdle and chromatophores on both the dorsal and ventral edges of the body in the caudal peduncle region. Unlike the type I specimens, only one chromatophore is present on the dorsal midline of the caudal peduncle region. A long series of 9 well-spaced chromatophores is present along the entire ventral margin of the body. The midbrain is sparsely pigmented and the midsection of the lower jaw has no pigmentation. The myomere count is identical with that found in type I.

The 3.7-mm. specimen (fig. 27), which was earlier identified as *A. thazard* (?) (Matsumoto, 1958a), appears similar to the 3.5-mm. specimen and has therefore been placed in this series.

A slightly larger specimen, 5.2 mm. (fig. 28), also has the same characteristics as the 3.5-mm. specimen, except for the pigmentation on the posterior part of the body. There are 3 very closely spaced chromatophores on the midventral line of the caudal peduncle region, and 4 more widely spaced chromatophore farther forward.

Several changes occur in the 7.2-mm. specimen (fig. 29). The first dorsal fin consists of 5 spines, and th second dorsal fin is represented by about 11 rays. The anal fin also shows signs of development, and abou

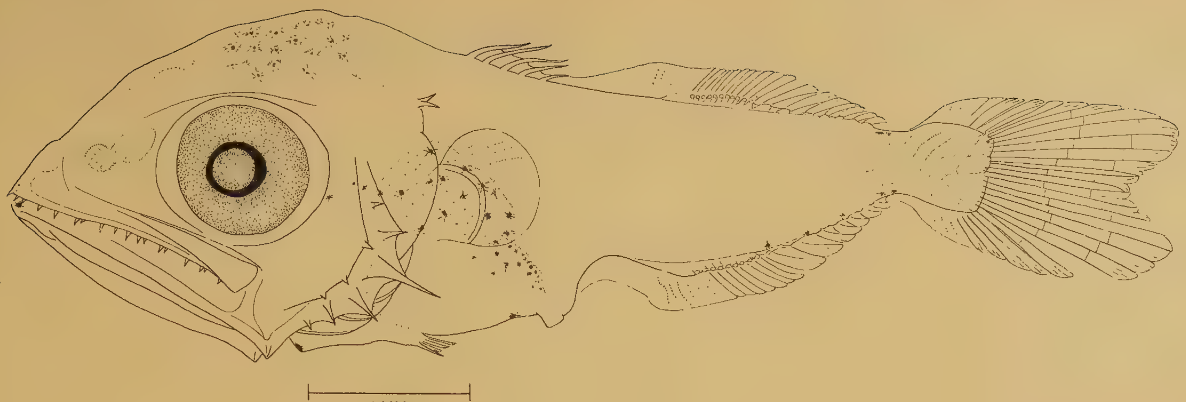

Figure 29. *Auxis* type II, 7.2 mm.

7 rays can be distinguished. The anal finlets, like their dorsal counterparts, are hardly noticeable. The caudal fin is quite advanced in development, and its posterior margin is beginning to fork. The ventrals are present, but they are still very small.

In general only minor changes in pigmentation are evident. Two very close-set chromatophores are present on the dorsal edge of the caudal peduncle, and 2 more similar ones are noticeable opposite them on the ventral edge. Anteriorly, 3 more well-spaced chromatophores are present along the bases of the anal finlets.

The series stops at about 8 mm., and all specimens above this size are referable to type I.

Discussion of Species Differences.

The two series of *Auxis* just described show minor differences only, the most obvious being the variation in pigmentation in the caudal peduncle region of specimens up to 8 mm. in total length. In type I there generally are 3 equally developed rows of pigment. In type II the middorsal edge of the caudal peduncle usually contains only one or two chromatophores, whereas the midlateral line has none. The midventral line of both series contains a group of 2 to 3 close-set chromatophores at the caudal peduncle and 3 to 6 well-spaced chromatophores farther forward. In specimens larger than 8.0 mm. the 3 rows of pigment seen in type I extend anteriorly with increasing numbers of chromatophores. Type II larvae of comparable sizes were not observed, and it is believed that both types assume a similar external appearance above this size.

One important observation which must be mentioned here is the extreme inconsistency of pigmentation on the midlateral line. In many specimens there are 1 to 5 chromatophores on one side of the body, but none on the other side. Such a wide variation in pigmentation between the two sides of the same fish renders the separation of *Auxis* into types I and II rather doubtful.

Judging on the basis of this, and also on the fact that the type II series stopped at about 8 mm., one may conclude that the two types are merely variants of a single species.

GEOGRAPHICAL DISTRIBUTION OF *EUTHYNNUS* AND *AUXIS* LARVAE

In spite of the wealth of larval and postlarval tunas taken by the "Dana" and other Danish vessels, this material was not treated quantitatively for several reasons. First, measurements of the volume of water strained by the sampling nets were not available; second, several types and sizes of nets were used in collecting the samples; third, the tows were all made with open nets which were hauled horizontally for lengths of time ranging from 5 minutes to 4 hours; and fourth, the number of levels at which the nets were towed generally varied from station to station, and the maximum depths, or more correctly, the maximum lengths of wire let out, also varied from 100 to 5,000 meters at different station. Thus, the distribution of the larvae can also be treated only qualitatively.

An examination of reports describing adult *Euthynnus* leads one to the conclusion that these fish normally live closer to land masses than other tunas. Our own observations on numerous POFI cruises in the central Pacific area seem to bear this out.

This association of adult *Euthynnus* with land masses is also seen, though to a lesser extent, in the captures of larvae and postlarvae in the Atlantic and Pacific Oceans. Figure 30 shows the positions where these larvae were taken on the several cruises in 1920–22 and 1928–30 by the "Dana" (*see* Appendix tables for station positions and numbers of larvae taken). Larval *Euthynnus* were taken in the Caribbean Sea, off the east coast of North America, off the coast of South America, in the Gulf of Panama, in the East Indies Archipelago, and off the west coast of Africa. Except for the few stations west of Sumatra, no samples from the Indian Ocean were available to us. It is interesting to note that no *Euthynnus* larva was taken in midocean, although there were numerous stations across both the Atlantic and Pacific Oceans. The farthest station from land at which a *Euthynnus* larva was recognized was about 300 miles; not a great distance as far as the fast-swimming adults are concerned.

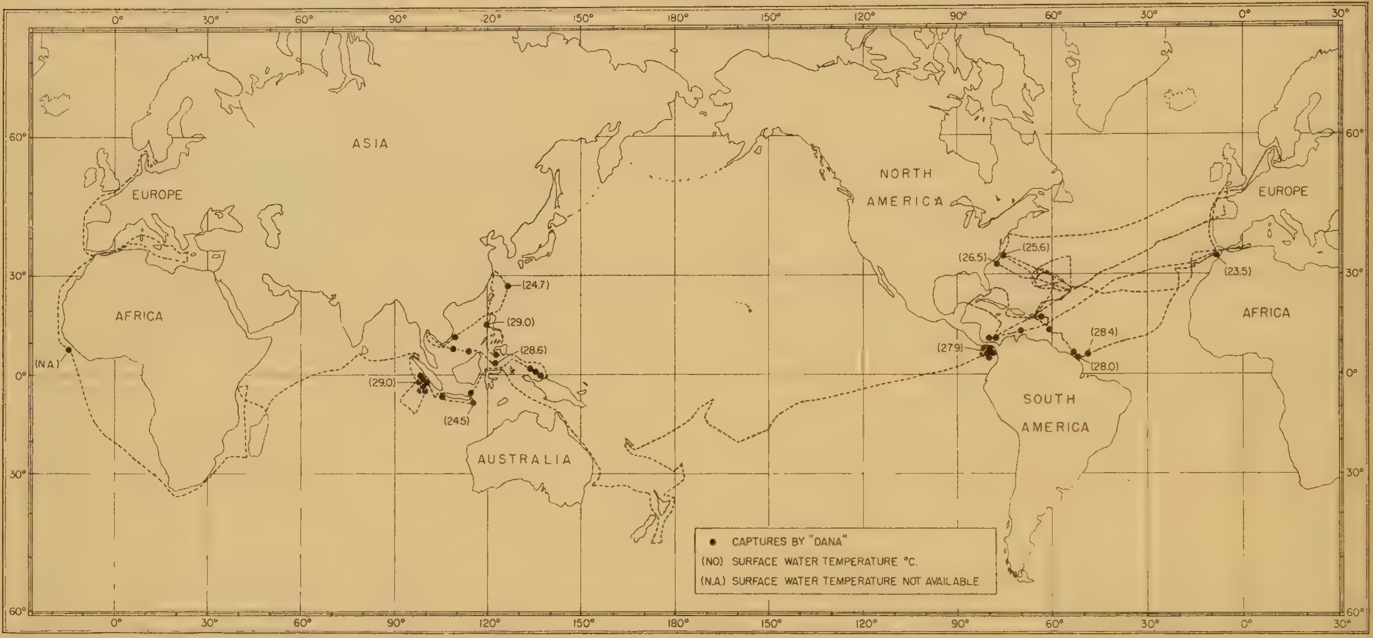

Figure 30. Localities of capture of *Euthynnus* larvae by the "Dana".

This is somewhat in contrast with the author's observations for *Katsuwonus pelamis* and *Neothunnus macropterus* larvae in the Pacific (Matsumoto, 1958a). Numerous larvae of these two species were taken in the equatorial current systems at midocean stations as well as at stations close to land masses.

Figure 30 also shows the extremes in surface water temperatures in which *Euthynnus* larvae were taken. In the western Atlantic these larvae were taken at water temperatures which ranged from 25.6° C. to 28.4° C. Temperatures from the two eastern Atlantic stations which yielded *Euthynnus* larvae were not available. However, at one station, 6 miles east of that shown near the northwest coast of Africa, the temperature was 23.5° C. In the Indo-Pacific area larvae were taken at water temperatures ranging from 24.5° C. to 29.0° C. Although there is no assurance that these values truly represent the lower and upper limits of temperatures tolerated by the young of *Euthynnus*, they at least give us an idea of the wide temperature range throughout which these larvae can exist.

The captures of *Auxis* larvae (fig. 31) indicate a slightly different distributional pattern. Although most of the larvae were taken in the same areas where *Euthynnus* larvae were captured, one individual was recognized in the catch from a midocean station in the Atlantic, approximately 1,200 miles from the nearest land mass. Comparable midoceanic catches were noted in the Pacific (Matsumoto, 1958a), where one larva was recorded from 1°42′ north latitude and 130°22′ west longitude, and another larva from 7° north latitude and 140° west longitude, approximately 800 and 900 miles, respectively, from the nearest land mass. From these midoceanic captures it can be surmised that *Auxis* is a more pelagic form than *Euthynnus*.

Figure 31 also shows the extremes in water temperatures in which *Auxis* larvae were taken. In the western Atlantic this range is comparable to that in which *Euthynnus* larvae were taken. The lowest temperature (23.3°C.) which yielded *Auxis* larvae was in the eastern Atlantic near the northwest coast of Africa. In the Indo-Pacific area, water containing *Auxis* larvae ranged from 22.5°C. to 29.0°C., the coldest water having been registered off the eastern coast of Australia.

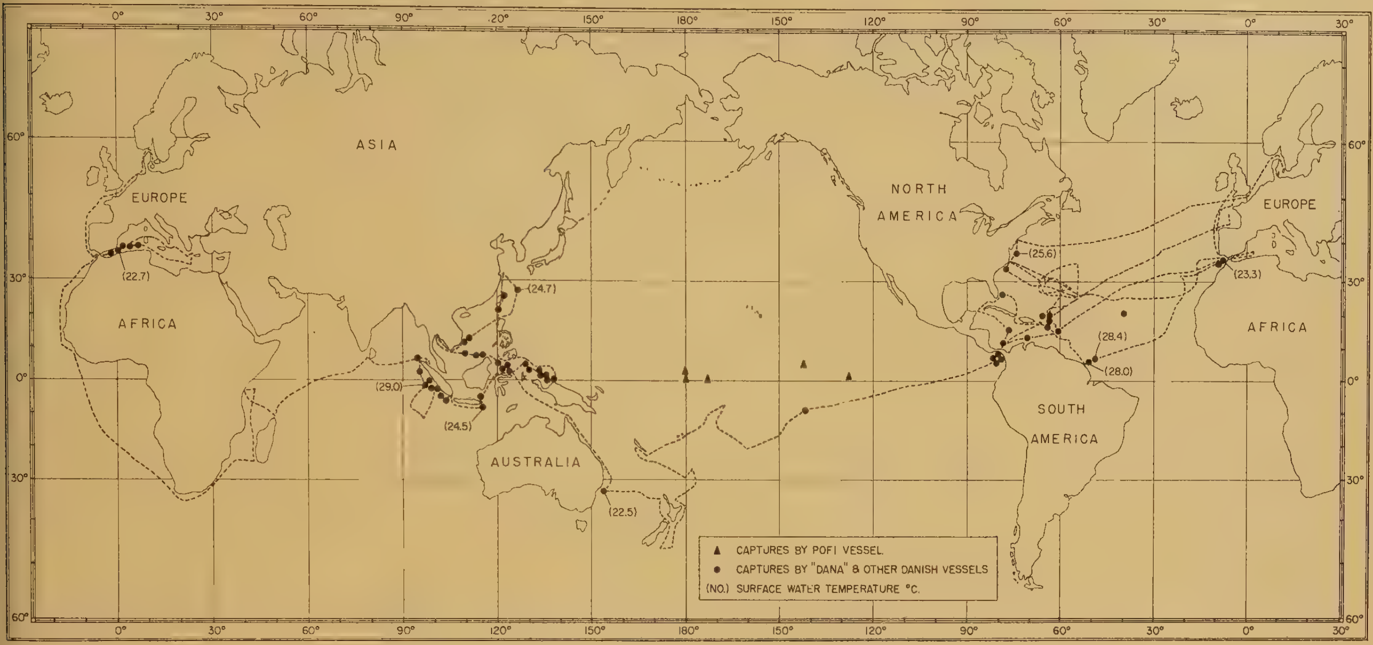

Figure 31. Localities of capture of *Auxis* larvae by the "Dana" and POFI vessel.

Although this bit of information is interesting and may suggest that *Auxis* larvae are able to withstand colder water than *Euthynnus* larvae, the amount of data available does not justify the formation of any reliable conclusion.

SPAWNING AREAS AS INDICATED BY LARVAL CATCHES

A large portion of the larvae of *Euthynnus* and *Auxis* consisted of recently hatched individuals measuring 3 mm. to 4 mm. Although many of these were recognized to genus, they were not positively identified to species. Because of this, only general statements are attempted here.

In a previous paper (Matsumoto, 1958a), it was hypothesized that recently hatched larvae of *K. pelamis* and *N. macropterus* measure approximately 3 mm.; that the larvae in this stage, like the eggs which precede them, are planktonic, their displacement from the spawning site being due to ocean currents alone; and that except in a few areas with exceptionally strong currents, this displacement is relatively insignificant. It was therefore believed that the localities where larvae of this size occurred represented the actual spawning sites. If we extend this reasoning to include larvae of *Euthynnus* and *Auxis*, on the assumption that the embryonic development of these species is similar to that of *K. pelamis* and *N. macropterus*, certain deductions can be made about their spawning areas.

Judging from the localities in which the adults and larvae of *Euthynnus* were taken, it may be said that this genus spawns in the vicinity of land masses. The same may be said of *Auxis*; but because its spawning sites also include oceanic situations, as indicated by larval capture in the middle of the Atlantic and as much as 900 miles from land in the Pacific (fig. 31), *Auxis* may be considered a more pelagic spawner than *Euthynnus*.

SUMMARY

1. Larvae and postlarvae of three species of *Euthynnus* (*E. alletteratus*, *E. lineatus* and *E. yaito*) and two forms of *Auxis* are described. Most of the material was collected by various Danish vessels, notably the research vessel "Dana" during an extended cruise in the North Atlantic and the Gulf of Panama from 1920–22, and during the round-the-world cruise from 1928–30. Other material included juveniles of *Euthynnus* and *Auxis* collected by various organizations from the Gulf of Mexico, the Pacific waters off Central America, and the Philippine waters.

2. Two types of *Auxis* larvae were noted in the samples. However, in the absence of conclusive evidence, it was hypothesized that the two types represented variations of the same species.

3. *Euthynnus* larvae were generally found in waters closer to land masses than larvae of other species of tunas.

4. The bulk of *Auxis* larvae was also found close to land, but captures in the middle of the Atlantic and up to 900 miles from land in the Pacific indicated that this genus spawns farther away from land than *Euthynnus*.

5. The presence of recently hatched larvae in the catches indicated that the locality of capture was in the vicinity of the spawning sites of these fishes.

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APPENDIX

The following tables list by species the number of larvae collected by Danish vessels from 1920 to 1937. Only the stations at which *Euthynnus* or *Auxis* larvae were taken are included in the tables. Additional hydrographic information at each of the stations may be obtained from *the Danish "Dana"-Expeditions 1920–22*, No. 1 (Schmidt, 1929); *Introduction to the Reports from the Carlsberg Foundation's Oceanographic Expedition Round the World 1928–30*, Dana-Report No. 1, (Tåning, 1934); and *List of Supplementary Pelagic Stations in the Pacific Ocean and the Atlantic*, Dana-Report No. 26, (Tåning, 1944).

Appendix **Table 1.** Record of *Euthynnus* captured. (All catches made by "Dana").

Station	Date	Latitude	Longitude	Wire out in meters	Surface temperature in centigrade	*Euthynnus yaito*	*Euthynnus lineatus*	*Euthynnus alletteratus*	Species unknown	Total
848	2- 6-20	18°00′N.	64°14′W.	Surf.	26.0	0	0	1	0	1
893	29- 7-20	33°07′N.	77°00′W.	100	26.5	0	0	4	0	4
893	–	–	–	150	–	0	0	5	0	5
952	12- 5-21	17°55′N.	64°48′W.	100	–	0	0	1	0	1
1172 (5)	14-11-21	7°22′N.	46°51′W.	50	28.4	0	0	1	0	1
1174 (2)	16-11-21	5°35′N.	51°08′W.	600	28.0	0	0	1	0	1
1174 (4)	–	–	–	100	–	0	0	2	0	2
1174 (5)	–	–	–	50	–	0	0	10	0	10
1175 (1)	17-11-21	5°06′N.	51°35′W.	200	–	0	0	1	0	1
1175 (2)	–	–	–	100	27.7	0	0	14	0	14
1175 (3)	–	–	–	50	–	0	0	2	0	2
1205 (1)	14- 1-22	6°49′N.	80°25′W.	Surf.	?	0	4 (1 juv.)	0	0	4
1205 (2)	–	–	–	600	?	0	1	0	0	1
1205 (4)	–	–	–	300	?	0	1	0	0	1
1205 (5)	–	–	–	100	?	0	13	0	0	13
1206 (2)	–	6°40′N.	80°47′W.	4000	?	0	4	0	0	4
1206 (3)	–	–	–	3500	?	0	1	0	0	1
1206 (4)	–	–	–	3000	?	0	1	0	0	1
1206 (5)	–	–	–	2500	?	0	2	0	0	2
1206 (10)	–	–	–	200	?	0	2	0	0	2
1206 (11)	–	–	–	100	?	0	58	0	0	58
1208 (2)	16- 1-22	6°48′N.	80°33′W.	600	?	0	1	0	0	1
1208 (3)	–	–	–	300	?	0	2	0	0	2
1208 (5)	–	–	–	3000	?	0	2	0	0	2
1208 (6)	–	–	–	2500	?	0	1	0	0	1
1208 (17)	–	–	–	1600	?	0	1	0	0	1
1211	18- 1-22	8°24′N.	79°23′W.	50	25.7	0	13	0	0	13
1212	19- 1-22	8°40′N.	–	35	?	0	25	0	0	25
1352 (2)	21- 5-22	35°42′N.	73°43′W.	200	25.6	0	0	0	3	3
1352 (3)	–	–	–	150	–	0	0	0	1	1
1352 (4)	–	–	–	100	–	0	0	0	2	2
1352 (5)	–	–	–	50	–	0	0	5(?)	0	5
3513 (1)	7- 7-28	34°25′N.	7°38′W.	150	(St. 3514 = 23.5)	0	0	0	11	11
3513 (7)	8- 7-28	–	–	300	–	0	0	0	1	1
3513 (9)	–	–	–	100	–	0	0	0	10	10
3515 (1)	11- 7-28	35°14′N.	6°51.5′W.	200	–	0	0	0	2	2
3515 (2)	–	–	–	150	–	0	0	0	8	8
3546 (1)	21- 8-28	13°11′N.	70°26′W.	300	27.5	0	0	2	0	2
3548 (7)	3- 9-28	7°06′N.	79°55′W.	100	27.9	0	2	0	0	2
3549 (3)	4- 9-28	7°16′N.	78°30′W.	100	28.0	0	1	0	0	1
3553 (1)	5- 9-28	7°55′N.	79°02′W.	100		0	1	0	0	1
3683 (7)	2- 4-29	4°03′N.	123°26′W.	600	28.6	1	0	0	0	1
3683 (10)	–	–	–	50	–	3	0	0	0	3
3688 (2)	8- 4-29	6°55 N.	114°02′E.	3500		15	0	0	0	15
3688 (3)	–	–	–	3000		23	0	0	0	23
3688 (4)	–	–	–	2000		25	0	0	0	25
3690 (2)	10- 4-29	8°02′N.	109°36.5′E.	600	28.0	1	0	0	0	1
3690 (3)	–	–	–	300	–	2	0	0	0	2
3690 (4)	–	–	–	100	–	42	0	0	0	42
3709 (2)	12- 5-29	12°15′N.	109°26′E.	50	28.9	1	0	0	0	1
3723 (4)	30- 5-29	20°30.5′N.	125°28′E.	100	24.7	2	0	0	0	2

Appendix **Table 1.** Record of *Euthynnus* captured. (All catches made by "Dana" (Cont'd).

Station	Date	Latitude	Longitude	Wire out in meters	Surface temperature in centrigrade	*Euthynnus yaito*	*Euthynnus lineatus*	*Euthynnus alletteratus*	Species unknown	Total
3723 (5) ...	30- 5-29	20°30.5′N.	125°28′E.	50	24.7	2	0	0	0	2
3731 (5) ...	16- 6-29	14°37′N.	119°52′E.	50	29.0	1	0	0	0	1
3757 (5) ...	16- 7-29	0°41.5′S.	134°14.5′E.	350		1	0	0	0	1
3757 (6) ...	–	–	–	250		3	0	0	0	3
3757 (7) ...	–	–	–	150		2	0	0	0	2
3759 (1) ...	–	0°40.5′S.	134°15′E.	400		7	0	0	0	7
3759 (2) ...	–	–	–	300		3	0	0	0	3
3759 (13) ..	–	–	–	500		10 (?)	0	0	0	10
3759 (14) ..	–	–	–	400		4	0	0	0	4
3759 (15) ..	–	–	–	300		4	0	0	0	4
3761 (5) ...	19- 7-29	0°33′S.	134°00′E.	400		11	0	0	0	11
3761 (6) ...	–	–	–	300		3	0	0	0	3
3761 (8) ...	–	–	–	150		1 (?)	0	0	0	1
3764 (2) ...	27- 7-29	1°01′S.	137°20′E.	400	28.2	2	0	0	0	2
3764 (4) ...	–	–	–	300	–	3	0	0	0	3
3768 (10) ..	24- 7-29	1°20′S.	138°42′E.	600		1	0	0	0	1
3768 (17) ..	25- 7-29	–	–	300		1	0	0	0	1
3800 (1) ...	18- 8-29	7°53′S.	116°18′E.	1000	27.4	1	0	0	0	1
3800 (5) ...	–	–	–	50	–	2 (?)	0	0	0	2
3804 (4) ...	30- 8-29	9°09′S.	114°47′E.	100	24.5	2	0	0	0	2
3809 (3) ...	4- 9-29	6°22′S.	105°12′E.	100	27.7	7 (?)	0	0	0	7
3809 (4) ...	–	–	–	50	–	13 (?)	0	0	0	13
3814 (6) ...	9- 9-29	4°38′S.	99°24′E.	150		1	0	0	0	1
3817 (4) ...	11- 9-29	2°00′S.	98°59′E.	100	29.0	1	0	0	0	1
3817 (9) ...	–	–	–	200	–	1	0	0	0	1
4817 (11) ..	–	–	–	100	–	2	0	0	0	2
3818 (1) ...	12- 9-29	2°07′S.	99°53′E.	300		1	0	0	0	1
3819 (1) ...	13- 9-29	1°29′S.	100°07′E.	300		2	0	0	0	2
3819 (2) ...	–	–	–	200		10	0	0	0	10
3821 (3) ...	14- 9-29	0°52′S.	99°25′E.	300	28.8	1	0	0	0	1
3821 (4) ...	–	–	–	200	–	11	0	0	0	11
3821 (5) ...	–	–	–	100	–	7	0	0	0	7
3860 (1) ...	19-10-29	2°57′S.	99°36′E.	350	28.7	1	0	0	0	1
3861 (3, 7)	21-10-29	3°12′S.	99°26′E.	200 & 250		1	0	0	0	1
4004 (4) ...	11- 3-30	10°21′N.	17°59′W.	100		0	0	0	2	2
Total larvae..............						238	135	49	40	462
Total juveniles..............						0	1	0	0	1
Total larvae and juveniles..............						238	136	49	40	463

Appendix **Table 2.** Record of *Auxis* captured.

Station	Vessel	Date	Latitude	Longitude	Wire out in meters	Surface temperature in centrigrade	*Auxis* type I	*Auxis* type II	Total
471	"Florida"	6- 4-12	20°44′N.	39°53′W.	15		0	1	1
893	"Dana"	29- 7-20	30°07′N.	77°00′W.	100	26.5	2	6	8
893	–	–	–	–	150	–	0	8	8
901	–	22- 2-21	17°55′N.	64°48′W.	100	27.0	1	0	1
1121	–	24- 9-21	36°38′N.	2°00′W.	25	24.3	1	0	1
1122 (2)	–	25- 9-21	37°12′N.	1°08′E.	200	23.8	0	1	1
1122 (4)	–	–	–	–	100	–	1	0	1
1123 (3)	–	26- 9-21	37°48′N.	2°44′E.	100	24.5	2	1	3
1123 (4)	–	–	–	–	50	–	1	1	2
1123 (5)	–	–	–	–	25	–	0	6	6
1125 (1)	–	30- 9-21	36°50′N.	2°58′E.	100		0	2	2
1126 (5)	–	1-10-21	37°06′N.	2°25′E.	100	22.7	0	1	1
1130 (3)	–	2-10-21	36°38′N.	2°00′W.	200	24.4	1	0	1
1172 (2)	–	14-11-21	7°22′N.	46°51′W.	600	28.4	5	0	5
1172 (3)	–	–	–	–	300	–	1	0	1
1172 (4)	–	–	–	–	100	–	33	0	33
1172 (5)	–	–	–	–	50	–	439	0	439
1173 (4)	–	15-11-21	6°18′N.	48°58′W.	100	27.5	1	0	1
1203 (5)	–	11- 1-22	7°30′N.	79°19′W.	50	?	0	1	1
1205 (1)	–	14- 1-22	6°49′N.	80°25′W.	Surf.	?	4	0	4
1205 (4)	–	–	–	–	300	?	0	1	1
1205 (5)	–	–	–	–	100	?	1	0	1
1206 (2)	–	–	6°40′N.	80°47′W.	4000	?	0	2	2
1206 (3)	–	–	–	–	3500	?	0	3	3
1206 (4)	–	–	–	–	3000	?	0	3	3
1206 (5)	–	–	–	–	2500	?	0	1	1
1206 (6)	–	–	–	–	Surf.	?	2	0	2
1206 (8)	–	–	–	–	800	?	2	0	2
1206 (10)	–	–	–	–	200	?	0	3	3
1206 (11)	–	–	–	–	100	?	0	14	14
1208 (5)	–	16- 1-22	6°48′N.	80°33′W.	3000	?	0	1	1
1208 (17)	–	–	–	–	1600	?	0	2	2
1212	–	19- 1-22	8°40′N.	79°30′W.	35	?	0	1	1
1214 (5)	–	26- 1-22	14°21′N.	76°50′W.	100	26.4	1	0	1
1214 (6)	–	–	–	–	50	–	1	0	1
1238 (4)	–	11- 2-22	26°13′N.	78°48′W.	100	23.6	3	0	3
1261 (4)	–	9- 3-22	19°04′N.	65°43′W.	100	?	1	0	1
1261 (5)	–	–	–	–	50	?	2	0	2
1281 (10)	–	1- 4-22	17°43′N.	64°56′W.	50	24.9	1	0	1
1283 (6)	–	5- 4-22	14°38′N.	61°16′W.	Surf.	26.1	3 (2 juv.)	0	3
1284 (6)	–	6- 4-22	–	–	Surf.	26.0	1	0	1
1285 (3)	–	7- 4-22	–	–	300	26.1	1	0	1
1285 (6)	–	–	–	–	Surf.	–	2 (1 juv.)	0	2
1289 (11)	–	15- 4-22	17°32′N.	64°56′W.	50	25.3	1	0	1
1292 (6)	–	16- 4-22	17°43′N.	–	50	25.4	1	0	1
1352 (2)	–	21- 5-22	35°42′N.	73°43′W.	200	25.6	2	4	6
1352 (3)	–	–	–	–	150	25.6	1	5	6
1352 (4)	–	–	–	–	100	–	3	11	14
1352 (5)	–	–	–	–	50	–	0	6	6
3513 (1)	–	8- 7-28	34°25′N.	7°38′W.	150	(St. 351 = 23.5	3	12	15
3513 (3)	–	–	–	–	50	–	0	7	7
3513 (7)	–	–	–	–	300	–	0	1	1
3513 (8)	–	–	–	–	200	–	0	1	1
3513 (9)	–	–	–	–	100	–	0	14	14
3515 (1)	–	11- 7-28	35°14′N.	6°51.5′W.	200	–	0	1	1
3515 (2)	–	–	–	–	150	–	0	3	3
3515 (3)	–	–	–	–	100	–	0	10	10
3546 (1)	–	21- 7-28	13°11′N.	70°26′W.	300	27.5	28	346	374
3546 (2)	–	–	–	–	200	–	206	0	206
3546 (3)	–	–	–	–	100	–	118	0	118
3547 (2)	–	24- 8-28	11°00′N.	77°40′W.	200	27.6	2	0	2
3547 (3)	–	–	–	–	100	–	3	0	3
3548 (7)	–	3- 9-28	7°06′N.	79°55′W.	100	27.9	0	1	1
3549 (3)	–	–	–	–	100	28.0	0	1	1
3553 (1)	–	5- 9-28	7°55′N.	79°02′W.	100		1	2	3
3553 (2)	–	–	–	–	50		2	3	5
3553	–	–	–	–	Surf.		0	1	1
3567 (1)	–	4-10-28	9°06′S.	140°21.5′W.	300		2	0	2
3567 (2)	–	–	–	–	100		1	0	1
3657 (1)	–	31- 5-29	33°17′S.	152°45′E.	1000	St. 3658 = 22.5	1	0	1
3657 (5)	–	–	–	–	50	–	8	2	10
3681 (3)	–	28- 3-29	0°29′N.	125°54′E.	300	28.5	1	0	1

Appendix **Table 2.** Record of *Auxis* captured (Cont'd).

Station	Vessel	Date	Latitude	Longitude	Wire out in meters	Surface temperature in centigrade	*Auxis* type I	*Auxis* type II	Total
681 (5)	"Dana"	28- 3-29	0°29′N.	125°54′E.	50	28.5	1	0	1
683 (8)	–	2- 4-29	4°03′N.	123°26′E.	300	28.6	0	1	1
683 (10)	–	–	–	–	50	–	1	4	5
684 (4)	–	3- 4-29	6°37′N.	122°24′E.	100	28.7	1	0	1
687 (4)	–	8- 4-29	7°14′N.	115°23′E.	100	27.8	1	1	2
687 (5)	–	–	–	–	50	–	0	1	1
688 (2)	–	–	6°55′N.	114°02′E.	3500		0	4	4
688 (3)	–	–	–	–	3000		0	3	3
688 (4)	–	–	–	–	2000		2	0	2
688 (5)	–	–	–	–	1000		0	2	2
690 (2)	–	10- 4-29	8°02′N.	109°36.5′E.	600	28.0	9	2	11
690 (3)	–	–	–	–	300	–	3	5	8
690 (4)	–	–	–	–	100	–	69	55	124
690 (5)	–	–	–	–	50	–	27	0	27
709 (2)	–	12 -5-29	12°15′N.	109°26′E.	50	28.9	1	1	2
723 (2)	–	30 -5-29	20°30.5′N.	125°28′E.	600	24.7	1	0	1
723 (3)	–	–	–	–	300	–	1	0	1
723 (4)	–	–	–	–	100	–	1	0	1
723 (5)	–	–	–	–	50	–	27	0	27
728 (3)	–	12- 6-29	24°15′N.	122°00′E.	300	27.1	0	1	1
739 (2)	–	2- 7-29	3°20′N.	123°50′E.	600	28.3	0	2	2
739 (4)	–	–	–	–	100	–	3	17	20
739 (5)	–	–	–	–	50	–	3	8	11
755 (4)	–	15- 7-29	0°30.5′S.	134°13′E.	100		1	3	4
755 (5)	–	–	–	–	50		4	5	9
757 (5)	–	16- 7-29	0°41.5′S.	134°14.5′E.	350		38	21	59
757 (6)	–	–	–	–	250		11	6	17
757 (7)	–	–	–	–	150		4	1	5
757 (8)	–	–	–	–	100		1	3	4
759 (1)	–	–	0°40.5′S.	134°15′E.	400		28	8	36
759 (2)	–	–	–	–	300		4	8	12
759 (3)	–	–	–	–	200		0	1	1
759 (4)	–	–	–	–	150		1	0	1
759 (13)	–	–	–	–	500		31	13	44
759 (14)	–	–	–	–	400		14 (1 juv.)	9	23
759 (15)	–	–	–	–	300		4	8	12
759 (16)	–	–	–	–	200		1	3	4
761 (5)	–	19- 7-29	0°33′S.	134°00′E.	400		7	22	29
761 (6)	–	–	–	–	300		3	4	7
761 (7)	–	–	–	–	200		3	2	5
761 (8)	–	–	–	–	150		4	3	7
764 (2)	–	21- 7-29	1°01′S.	137°20′E.	400	28.2	2	0	2
764 (4)	–	–	–	–	300	–	3	4	7
766 (6)	–	22- 7-29	1°13′S.	138°43′E.	600		1	0	1
766 (15)	–	–	–	–	300		1	0	1
768 (7)	–	24- 7-29	1°20′S.	138°42′E.	600		1	0	1
768 (16)	–	–	–	–	400		3	1	4
768 (17)	–	25- 7-29	1°20′S.	138°42′E.	300		1	1	2
772 (1)	–	27- 7-29	0°37′S.	134°29′E.	500		0	2	2
772 (2)	–	–	–	–	400		1	1	2
772 (3)	–	–	–	–	300		1	1	2
772 (4)	–	–	–	–	100		0	1	1
775 (3)	–	29- 7-29	0°02′S.	131°18′E.	200	28.4	1	3	4
775 (4)	–	–	–	–	100	–	1	0	1
779 (3)	–	1- 8-29	0°28′S.	126°47′E.	150		3	0	3
800 (2)	–	18- 8-29	7°53′S.	116°18′E.	600	27.4	0	1	1
800 (3)	–	–	–	–	300	–	10	0	10
800 (4)	–	–	–	–	100	–	3	0	3
800 (5)	–	–	–	–	50	–	4	0	4
804 (2)	–	30- 8-29	9°09′S.	114°47′E.	600	24.5	2	1	3
804 (3)	–	–	–	–	300	–	6	2	8
804 (4)	–	–	–	–	100	–	70	16	86
817 (2)	–	11- 9-29	2°00′S.	98°59′E.	600	29.0	0	1	1
817 (4)	–	–	–	–	100	–	1	0	1
817 (5)	–	–	–	–	50	–	1	1	2
817 (6)	–	–	–	–	200	–	2	0	2
817 (7)	–	11- 9-29	2°00′S.	98°59′E.	150	29.0	2	0	2
817 (8)	–	–	–	–	100	–	1	0	1
817 (9)	–	–	–	–	200	–	2	0	2
817 (10)	–	–	–	–	150	–	2	0	2
817 (11)	–	–	–	–	100	–	10	0	10
819 (2)	–	13- 9-29	1°29′S.	100°07′E.	200		9	1	10

Appendix **Table 2.** Record of *Auxis* captured (Cont'd).

Station	Vessel	Date	Latitude	Longitude	Wire out in meters	Surface temperature in centigrade	*Auxis* type I	*Auxis* type II	Total
3819 (3)	"Dana"	13- 9-29	1°29′S.	100°07′E.	100		4	1	5
3821 (2)	–	14- 9-29	0°52′S.	99°25′E.	600	28.8	1	0	1
3821 (4)	–	–	–	–	200	–	5	0	5
3821 (5)	–	–	–	–	100	–	21	0	21
3822 (1)	–	–	–	–	200		7	0	7
3822 (3)	–	–	1°00′S.	98°12′E.	100		4	0	4
3830 (1)	–	19- 9-29	–	–	300	28.1	2	0	2
3830 (4)	–	–	2°36′N.	96°31′E.	100	–	0	1	1
3838 (1)	–	25- 9-29	1°47′S.	100°08′E.	300		3	0	3
3860 (1)	–	19-10-29	2°57′S.	99°36′E.	350	28.7	4	1	5
3860 (5)	–	–	–	–	400	28.7	1	0	1
3860 (7)	–	–	–	–	300	–	1	0	1
3860 (12, 17)	–	–	–	–	250	–	3	2	5
3860 (8)	–	–	–	–	250	–	1	0	1
3860 (9, 13)	–	–	–	–	400	–	2	0	2
3860 (11, 15)	–	–	–	–	300	–	5	2	7
3860 (20)	–	–	–	–	600	–	2	0	2
3860 (22)	–	–	–	–	100	–	2	0	2
3860 (23)	–	–	–	–	50	–	2	0	2
3861 (3, 7)	–	21-10-29	3°12′S.	99°26′E.	200 & 250		2	0	2
3903 (3)	–	17-11-29	5°50′N.	93°28′E.	300		3	0	3
3903 (5)	–	–	–	–	50		2	1	3
4002	–	7- 3-30	8°14′N.	13°37′W.	50		1	0	1
4772	"Pacific"	12- 4-33	21°40′N.	120°02′E.	201	26.0	0	7	7
4819	–	22- 6-37	12°01′N.	111°38′E.	201	31.0	0	1	1
Total larvae							1,425	770	2,195
Total juveniles							4	0	4
Total larvae and juveniles							1,429	770	2,199

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Effect of Water Clarity on Albacore Catches

Garth I. Murphy

Effect of Water Clarity on Albacore Catches

GARTH I. MURPHY

Fishery Research Biologist, U. S. Fish and Wildlife Service, Honolulu, Hawaii

ABSTRACT

The numbers of albacore (*Germo alalunga*) taken by gill-netting and surface trolling are seriously affected by the transparency of the water. Observations assembled from a fishing cruise between Hawaii and the Aleutians in 1956 and from a cruise off the Pacific coast of North America in 1957 showed that the efficiency of the troll was greater in clear water than in more turbid water. Very likely this increase in efficiency is a power function of the change in transparency. Though the data are not so convincing, the results suggested that the gill net fishes more efficiently in turbid water. The ratio of troll catch to gill-net catch bears the following relation to a reciprocal function of the extinction coefficient—

$$\frac{\text{Troll} \times 100}{\text{Gill net}} = .0000394 \left(\frac{1.7}{\text{Extinction coefficient}}\right)^{4.55}$$

Since the theoretical maximum power function of the troll catches alone is about 3, the residual of 1.55 may be associated with the reverse effect that water clarity has on the efficiency of the gill net.

These data are discussed in relation to evaluating the abundance of any species of fish when the method of assessment involves visual responses. In addition, the possibility is discussed that water clarity may be an important ecological factor in the ocean in that the efficiency of sight feeders will be reduced as turbidity increases.

INTRODUCTION

Students of the ocean have long recognized that water clarity is an important ecological variable through its effect on photosynthesis (Clarke 1939) and on the maximum depth at which organisms might be able to see (Clarke 1936). Tamura (1957) and other investigators have concerned themselves with the morphology and histology of fish eyes and with measurements of the thresholds of vision in terms of illumination and of the most efficient level of illumination for vision (Tamura *et al.* 1957). Finally, in recent years there has been considerable attention devoted to variation in the optical properties of ocean water with depth (Jerlov 1951). Our concern is with a slightly different aspect of the problem. We wish to consider how far a fish can see in its normal habitat (a quantity similar to visual range as defined by Jenkins and Bowen 1946), and its effect on distribution and sampling of the fish.

In 1955 the writer hypothesized that the clarity of oceanic waters may have a direct influence on the abundance and distribution of tunas through its effect on their ability t forage. The hypothesis seemed to hav merit, and observations and preliminar investigations pertinent to the problem wer initiated shortly thereafter. A study of th morphology and histology of tuna eyes wa begun under contract at the University o Hawaii, and we began measuring wate clarity in connection with fishing survey insofar as instrumentation and time permitted.

The material to be presented here doe not permit direct discussion of the primar hypothesis. Rather, it shows that method of catching tuna that depend on visual response of the fish are efficient in proportio to the clarity of the waters—by implicatio supporting the original hypothesis. The evidence shows that trolling, which depends o a positive visual response, is most efficier in clear water, whereas gill-netting, which dependent on non-response, is most efficient in turbid water.

MATERIALS AND METHODS

The data utilized in this study were collected during the course of two albaco

(*Germo alalunga*) fishing surveys. The first survey was conducted in the summer of 1956 in temperate waters lying between Hawaii and the Aleutian Islands. The second survey was made during the summer of 1957 in the waters off the west coast of the United States. For the purposes of this study pertinent observations were grouped into synthetic stations. These are centered on overnight gill-net sets, and also include trolling during the afternoon preceding and the morning following the gill-net sets. Daylight extinction measurements were made near mid-day before and after the gill-net sets.

Daylight extinction was measured by determining the depth at which 5 per cent and 10 per cent of the surface illumination persisted. The apparatus consisted of a deck cell, mounted on gimbals and containing a Weston Photronic Model 856 type 1 photoelectric cell, and a similar submerged cell, each equipped with a suitable filter to match its response to the standard luminosity curve adopted by the International Commission on Illumination. A microammeter completed the apparatus. Determinations were made by placing an appropriate calibrated cover over the deck cell and lowering the sea cell until its current output equalled that of the deck cell. The two determinations (5 and 10 per cent) were coverted to extinction coefficients (Sverdrup *et al.* 1942, p. 82), and the two extinction coefficients were averaged. As might be expected from the differential extinction of different wave lengths of light through a water column and the possibility of heterogeneity of the water columns, the two coefficients (5 and 10 per cent) were not identical, but they generally bore a linear relation to one another and to the average of the two, suggesting that the average coefficient is a useful relative measure of transparency.

A final problem with respect to the extinction coefficients was to derive a value for each synthetic station that would be representative of clarity during trolling and gill-netting. Since ordinarily the ship moved 10–60 miles from one noon to the other, that is, from one light measurement to the next, there were no transparency observations directly associated with the gill-netting. Though somewhat unsatisfactory, our method of solving the difficulty was to average the two noon values of clarity bracketing the fishing, on the assumption that transparency varied linearly between stations. The light penetration measurements when plotted on surface charts to check this assumption indicated that, by and large, transparency varied in a progressive manner over a noon-to-noon vessel track. In three instances additional values obtained two or three days before or after a synthetic station were included because they fell on the vessel track. Thus each extinction coefficient employed here usually is the mean of four field determinations: two (5 and 10 per cent) at the noon preceding the fishing effort; and two (5 and 10 per cent) at the noon immediately following the fishing effort. It should be noted that the most turbid water encountered corresponded roughly to the oceanic maximum recognized by Sverdrup *et al.* (1942, p. 85) and that none would fall in the category of coastal water with respect to turbidity.

Trolling was generally carried out with the vessel proceeding at 5–7 knots, trailing 5 or 6 lines. These lines bore a variety of "albacore lures," and there was no indication from the catch that one lure was superior to the others. No adjustments were made in the raw troll catches except for one station during which there was no trolling on the morning following the gill-net station. In that instance the troll catch of the afternoon preceding the gill-net station was arbitrarily doubled.

The albacore gill nets were made up of shackles about 300 feet long and 30 feet deep, with mesh size ranging from 4½ to 7½ inches (stretched measure). Between 9 and 18 shackles were fished at each station, 12 being the typical number. Since all mesh sizes took albacore, we have made no attempt to adjust the catch for varying proportions of the different mesh sizes. Rather, the results are expressed in terms of catch per 12 shackles of net. Gill nets were set at dusk and hauled just prior to dawn.

Approximately 35 sets of fish-catch and transparency measurements were available

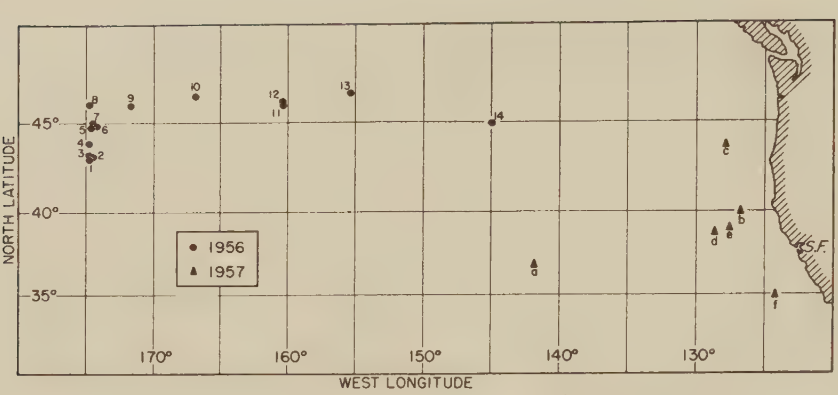

Fig. 1. Northeastern Pacific Ocean, showing the locations of troll and gill-net stations used in this study. The July-August 1956 cruise is represented by solid circles and the June-August 1957 cruise by triangles.

Table 1. *Albacore catches and mean extinction coefficients during 1956 and 1957*

Dates and positions refer to the start of the gill-net stations. Gill-net catches are adjusted to 12 shackles. Troll catches are from noon to noon bracketing the gill-net stations. Extinction coefficients are the means of the 10 and 5 per cent determinations of all light stations during the noon-to-noon periods.

Station	Date	Latitude	Longitude	Gill-net catch	Troll catch	Extinction coefficient
1	7-25-56	43° 02′ N	174° 57′ W	27	5	.119
2	7-26-56	43° 07′ N	174° 52′ W	81	1	.137
3	7-27-56	43° 10′ N	174° 53′ W	33	1	.148
4	7-28-56	43° 56′ N	174° 57′ W	16	1	.157
5	7-31-56	44° 48′ N	174° 46′ W	112	11	.086
6	8-1-56	44° 54′ N	174° 08′ W	32	11	.090
7	8-2-56	44° 58′ N	174° 29′ W	33	6	.094
8	8-3-56	46° 01′ N	174° 58′ W	16	0	.089
9	8-16-56	45° 57′ N	171° 44′ W	53	4	.095
10	8-19-56	46° 28′ N	166° 54′ W	33	3	.130
11	8-21-56	46° 00′ N	160° 16′ W	63	0	.130
12	8-22-56	46° 03′ N	160° 16′ W	79	0	.149
13	8-26-56	46° 25′ N	155° 15′ W	13	0	.116
14	9-1-56	44° 57′ N	145° 01′ W	4	7	.106
a	6-19-57	36° 53′ N	141° 41′ W	27	4	.052
b	7-9-57	39° 59′ N	126° 51′ W	3	12	.063
c	7-23-57	43° 42′ N	127° 53′ W	11	12	.072
d	7-28-57	38° 45′ N	128° 37′ W	2	15	.055
e	7-29-57	39° 00′ N	127° 31′ W	28	6	.074
f	8-9-57	34° 50′ N	124° 10′ W	2	13	.071

for study. These were reduced to 20 by considering only those stations in which the aggregate catch of the gill-net set and the trolling was 10 or more fish. This limitation reduced the variability in the data and, perhaps even more important, restricted the study to waters in which albacore were present in fair numbers. Thus, the problem of the general distribution of albacore and the possible interaction of other environmental factors on the catches, such as temperature, is minimized. The locations of the 20 stations that met the above criterion are shown in Figure 1 and the data are tabulated in Table 1.

RESULTS

The results of gill-netting show little numerical relation to the troll catches (Fig. 2). Though far below the level of statistical significance, the two have a negative correlation coefficient as would be expected if they are affected in opposite ways by water clarity. Statistically significant results should not be expected, however, without enormous amounts of data, because the treatment does not overcome variations in the absolute abundance of albacore from station to station; and since two measures of abundance are plotted, this effect is doubled.

Troll catches, plotted as a function of water clarity (extinction coefficient), show a negative relation ($r = -0.738$, $P < 0.01$) (Fig. 3). A linear function was applied, not because it is proposed that the two variables bear a linear relation to each other, but rather as a simple way to show that there is an association between them. Again, an unknown source of variability in this treatment must be the changes in the true abundance of albacore from station to station. However, the effect of this source of variability is less than in the previous analy-

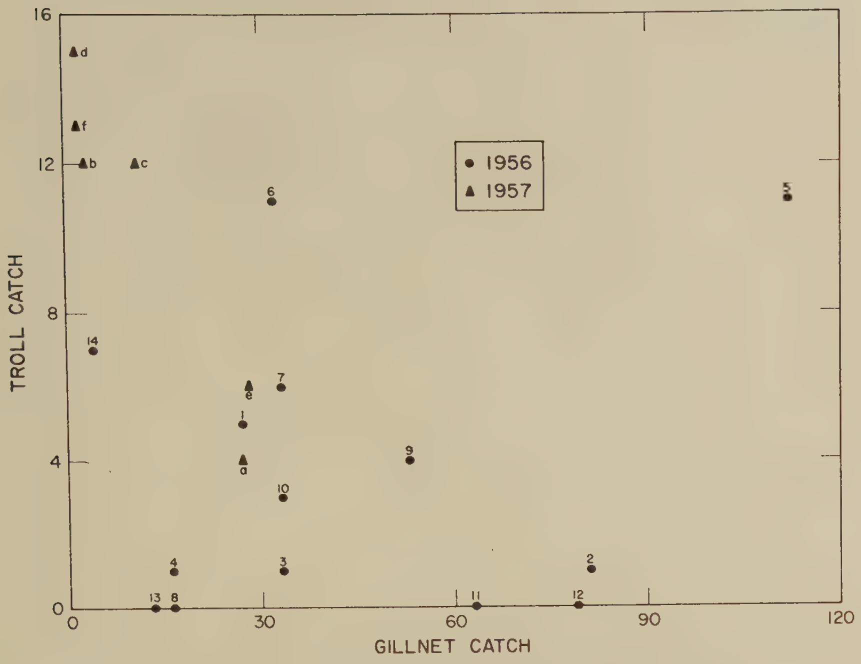

FIG. 2. Troll catch of albacore, plotted against the gill-net catch.

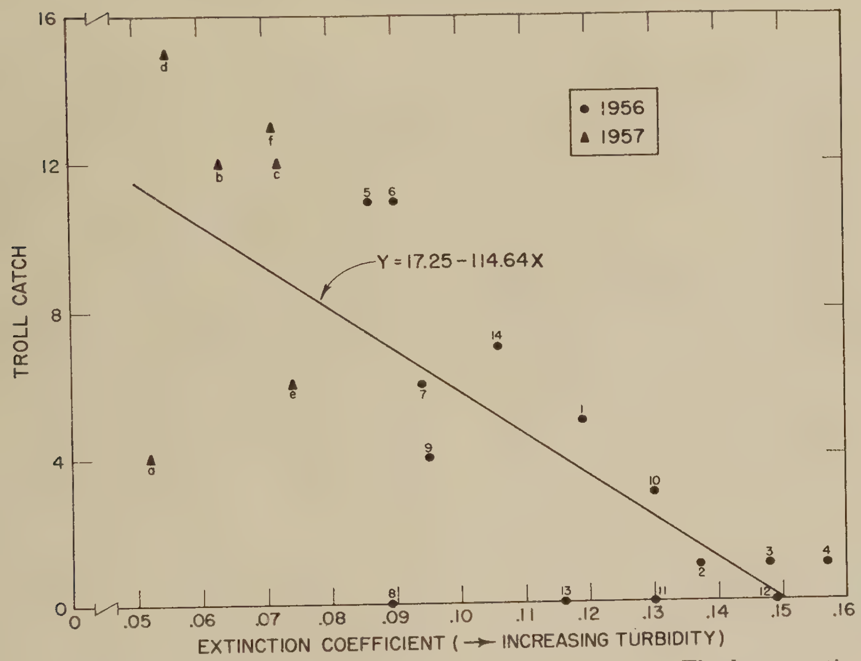

FIG. 3. Albacore troll catches plotted against water transparency. The larger extinction coefficients represent less transparent water.

sis because we consider only one measurement of the albacore population. Figure 3 could, of course, be interpreted to mean that albacore are most abundant in clear water or that trolling is most effective in clear water or, as a third possibility, there may be an interaction or systematic effect of the different variables.

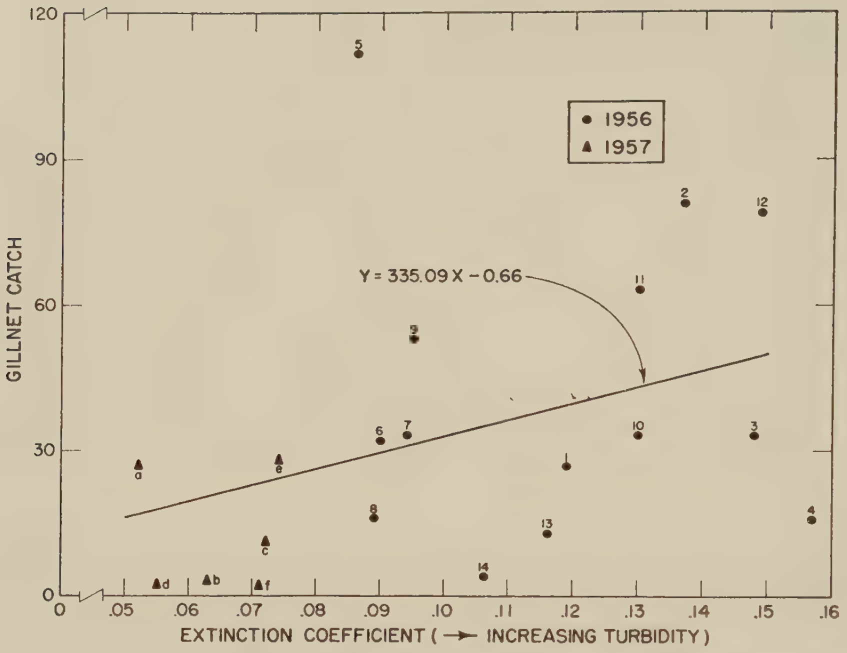

FIG. 4. Albacore gill-net catches plotted against water transparency. The larger extinction coefficients represent less transparent water.

Gill-net catches plotted against turbidity show a positive relation (r = 0.36, P > 0.05) (Fig. 4). Lack of statistical significance may well stem from the ever-present variability associated with differences in the actual density of the albacore population and the tendency for night gill-netting to reduce or perhaps even eliminate the effect of variations in water clarity. Auxiliary sources of light must also be considered with respect to the gill net. Extremely clear water is generally low in biomass and probably would produce little bioluminescence in the vicinity of the drifting gill net. Turbid water in the marine environment is generally high in biomass and might therefore result in high bioluminescence. This additional variable would operate to reduce the slope of the regression.

If we accept the slope in Figure 4, we are again offered three alternate conclusions: (1) that albacore are more abundant in more turbid water, (2) that the gill net fishes more efficiently in more turbid water, or (3) that there is systematic interaction among the variables. These are opposite to the conclusions drawn from the troll catches. If the slope, which falls slightly short of significance, is rejected in compliance with the usual statistical standards, we can conclude that the magnitude of the gill-net catch and presumably the density of the albacore population is independent of water clarity.

The preceding analyses of water clarity and albacore catches were handicapped by inability to estimate or control variations in absolute abundance from station to station. One way to eliminate the effect of absolute abundance is to express the catches as a ratio (Troll catch ÷ Gill-net catch), adding "1" to the three zero catches in Table 1. If these ratios are plotted against water clarity, the slope obtained will be independent of abundance and should only reflect the relative efficiency of the two sampling methods with respect to water clarity. This treatment has the disadvantage of introducing into one analysis all sources of random variability, that is, variability in gill-net catches, troll catches, and random errors in assessing water clarity.

In this final analysis an approximation of

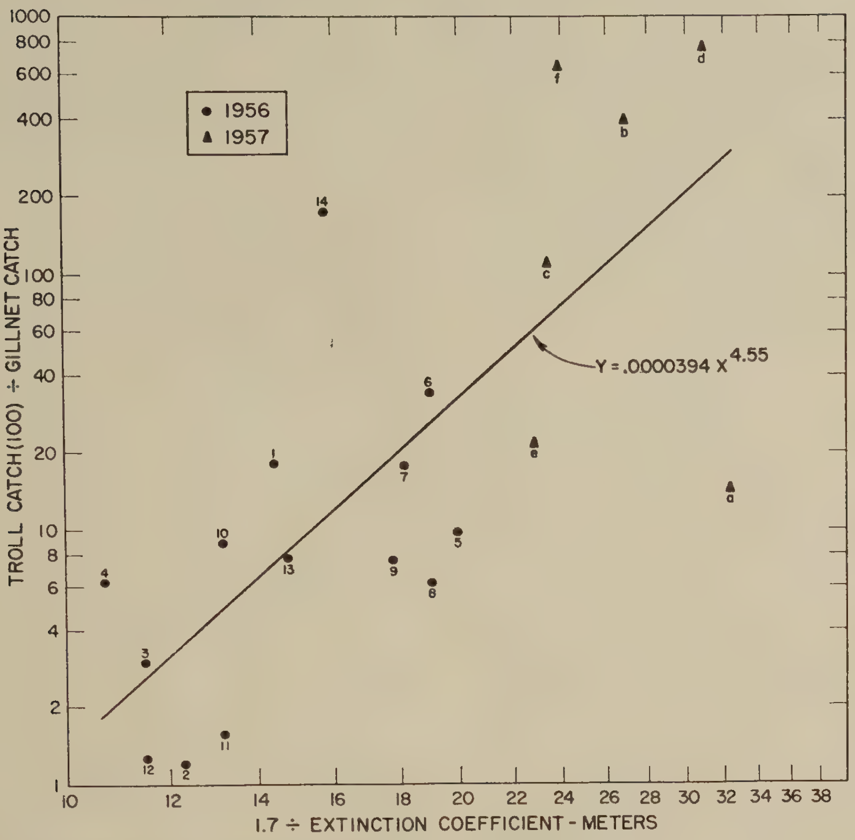

FIG. 5. The ratio of troll to gill-net catches plotted as a function of the reciprocal of the extinction coefficient.

the distance an albacore can see (visual range), *i.e.*, $\frac{1.7}{K}$ is employed as the measure of water clarity instead of the extinction coefficient (K). This reciprocal quantity of the extinction coefficient was found by Poole and Atkins (1929) to be equal to the vertical depth at which a Secchi disk could be seen in the English Channel. A comparison of our Secchi disk measurements and the computed $\frac{1.7}{K}$ indicates the latter is also a good approximation in these waters. (The observed Secchi disk measurements were not used in the present study because they lack the precision of the photoelectric determinations, principally because of variation in boundary conditions at the sea surface.)

The relative efficiency of the two sampling methods $\left(\frac{\text{Troll} \times 100}{\text{Gill net}}\right)$ is treated as a power function of the visual range $\left(\frac{1.7}{K}\right)$ because the efficiency of the troll should be related to some power of the radius of vision, that is, the visual range. Thus the following type of equation should obtain—

$$\frac{\text{Troll} \times 100}{\text{Gill net}} = a\left(\frac{1.7}{K}\right)^b$$

The empirical solution to the above equation (Fig. 5) gives a value of 3.95×10^{-5} for a and 4.55 for b. The slope is highly significant ($P < 0.001$) as is the associated correlation ($r = 0.772$). Again, as suggested by the other treatments, the efficiency of the troll in respect to the gill net is apparently a function of water clarity. This analysis tends to implicate the gill net as well as the troll, because the b value (4.55) is higher than might be expected if the gill net is unbiased with respect to water clarity. That is, if an instantaneous function is considered, the volume of water in which the troll lure is visible to albacore should be close to a cube function of the visual range because an object near the surface is visible to all fish in a "hemisphere," with locus at the object and a radius equal to the visual range.[1] No significantly higher exponent can be theorized, so most of the residual (1.55) must be either related to increasing gill-net efficiency with increasing turbidity or to sampling error or both.

DISCUSSION

The validity of using extinction coefficients (K) to estimate how far a fish can see is not clearly established. Poole and Atkins (1929) showed that in the English Channel $\frac{1.7}{K}$ was a linear function of the vertical limit of Secchi disk visibility. The present problem, however, involves vision at all angles from the horizontal to the vertical. We have made measurements comparing vertical and horizontal Secchi disk visibility at two locations in Hawaiian waters with the observer on a submerged platform about 4 feet below the sea surface. In each of two pairs of observations, one determination was made vertically and a second, with a similar target, horizontally, the target being suspended from a buoy about 10 feet below the surface. In each instance the vertical and horizontal determinations were nearly identical, varying about 10 feet (vertical distances 150 and 180 feet). Thus the vertical Secchi disk determinations appear to provide a fairly close approximation of horizontal visual range. Since this quantity is a function of the extinction coefficient it appears that the use of $\frac{1.7}{K}$ as a first approximation of visual range is justified. The basic reason for the validity of this approximation lies in fact that loss of contrast through scattering is the most important element in fixing "visual range" in the open ocean, with absolute level of initial illumination of minor importance (Duntley 1952).

Perhaps it is redundant to point out that the evidence given questions the validity of estimates of tuna abundance if the methods are such that the fish can employ vision in a positive or negative sense in relation to the gear. A case in point are Figures 3, 4, and 5 in which the data for 1957, while not incompatible with those obtained in 1956, are not randomly distributed with respect to the 1956 results. This apparently resulted because gill-net stations in 1957 were deliberately located in areas where trolling was "good," practically precluding a random distribution of gill-net catches with respect to water clarity. Comprehensive sampling programs employing two or more types of gear might help to overcome this problem, and more precise information on the magnitude of the effect of water clarity and other environmental factors on the efficiency of the sampling method might permit adjustment of catches to obtain a more reliable measure of actual abundance. Another alternative is to sample by means of measures not dependent on any reaction of the fish to visual stimuli. For instance, the gill net as used for albacore appears to be an improvement over the troll, though the gill net might be more susceptible to other factors such as the vertical distribution of fish and the thermal structure of the water. An ecologist attempting to relate abundance of, say, albacore to other factors in the environment might even better be served by the uncertain but unbiased estimates of fish abundance that might be obtained by echo sounders.

Though it is not possible to treat the subject with any precision, it is worthwhile to consider further the possible effect of water clarity on the absolute abundance of albacore and other sight feeders. The first problem, of course, is to establish that they are sight feeders. This is indicated with respect to lbacore and other tunas by general observations on their behavior at sea and by uch objective data as failure to make captures at night by trolling. It is also suggested by their large and presumably efficient eyes and by their ability to swim rapidly. Vision in the open ocean appears o be related to turbidity, which is of course related to the amount of particulate matter n the water. In the open ocean the amount of particulate matter is at least in part a function of the biomass; thus as the standing crop of food increases, the relative ability of the tunas to locate and capture a prey animal must decrease. Fish such as tuna might then be at a loss in an environment judged ideal on the basis of the standing crop of organisms. An extreme case of this effect might run as follows: A particular area contains a crop of tuna forage sufficient to support a particular density of tuna. An ncrease in the rate of replenishment of nutrients in that area through upwelling or some other phenomenon causes an upsurge of phytoplankton, thus decreasing the visibility. However, there might not yet be an increase in the tuna food supply so the tunas would be forced temporarily to desert this particular area. Perhaps this effect contributes to the reported exclusion of herring from dense populations of phytoplankton, for they also appear to employ vision in capturing food (Vilter 1950).

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[1] The cube function is only an approximation because an object can be seen over the greatest range from directly below, and at a lesser distance from a horizontal direction (Duntley 1952). Thus the volume of water in which the lure is visible is an ellipsoidal solid with a vertical axis slightly greater than the horizontal. The present data do not permit precise resolution of the parameters involved, but trial computations show that no more than 0.2 of the 1.55 can be ascribed to deviations from a sphere.

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A SURVEY OF THE AMERICAN AND JAPANESE ALBACORE TUNA FISHERIES IN THE PACIFIC THROUGH EXAMINATION OF CATCH STATISTICS

By Tamio Otsu*

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ABSTRACT

Catch statistics of the American and Japanese albacore fisheries in the temperate and tropical Pacific Ocean are presented. There has been a fourfold increase in Pacific albacore landings since the prewar years. The Japanese account for about 75 percent of the landings.

Judging by catch statistics alone, the two Japanese North Pacific fisheries appear to be quite stable, even at the present high level of production. There is no indication of a declining resource. While the Japanese South Pacific fisheries are relatively recent in origin, and have not stood the test of time, the present status is encouraging. The American fishery has been beset with marked fluctuations in landings but there is no evidence that fishing has adversely affected the stock.

All indications on the present status of the albacore fisheries point to the parallel rise in effort and catch.

INTRODUCTION

The three major fisheries for albacore tuna, Germo alalunga (Bonnaterre), in the Pacific, all of which are located in the Temperate Zone of the North Pacific Ocean are: (1) the Japanese spring and summer live-bait fishery, (2) the United States west coast summer and fall fishery, and (3) the Japanese winter long-line fishery. In addition, the Japanese tuna long-liners catch much albacore in the tropical Pacific (see fig. 1).

Statistics from each of these fisheries are presented. Certain biological information is also examined for possible clues to the relationship of fish making up the stocks in the various fisheries. By examining the statistics, it is hoped that enough evidence can be gathered which will lead to a knowledge of the population structure of the Pacific albacore, and more important, to a definition of the present status of this important resource. For a population study, much more detailed statistics than are available would be required.

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* Fishery Research Biologist, Pacific Oceanic Fishery Investigations, U. S. Bureau of Commercial Fisheries, Honolulu, T. H.

This study as well as others pertaining to the albacore resources in the Pacific are being conducted by the Pacific Oceanic Fishery Investigations of the U. S. Bureau of Commercial Fisheries under Public Laws 329 (80th Congress) and 466 (Saltonstall-Kennedy Act, 83rd Congress).

MAJOR PACIFIC ALBACORE FISHERIES

JAPANESE SPRING AND SUMMER LIVE-BAIT FISHERY: A description of this fishery has been given by Van Campen[1], and only a few of the more important points are repeated here. This fishery is conducted near Japan from late April to July, and is a part of the more extensive pole-and-line fishery for skipjack (*Katsuwonus pelamis*). Boats fishing for skipjack tuna, which appear in early spring off southern Japan, begin to fish for albacore which become available off central Honshu, Japan, about late April or early May. The surface schools of albacore follow the northward extension of the warm Kuroshio Current along the coast of Japan; their availability quickly reaches a peak in June, and then rapidly drops off as schools move farther offshore to the eastward. During July, the boats begin to return to skipjack fishing as the albacore go out of range or disperse and become harder to locate. Van Campen has pointed out that in recent years there was an eastward extension of the albacore grounds from about 155° E. to 165° E. longitude, and that this undoubtedly reflects the growing proportion of larger vessels in the fleet which are able to go farther offshore in pursuit of the fish.

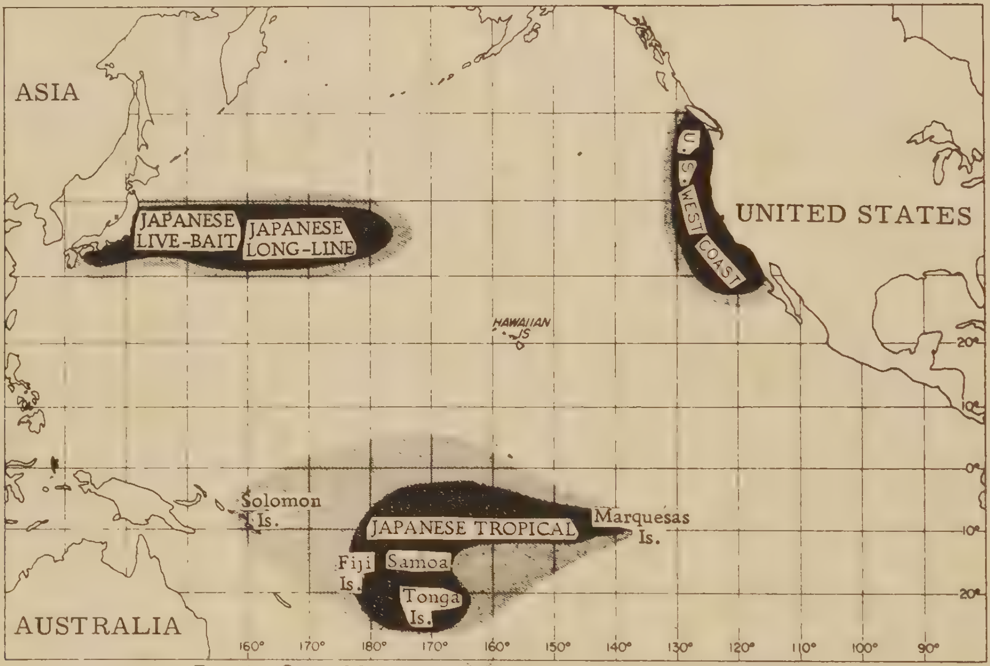

Fig. 1 - General localities of the major Pacific albacore fisheries.

UNITED STATES WEST COAST SUMMER AND FALL FISHERY: The albacore occurs along the Pacific Coast of North America from southern Baja California to Alaska between latitudes 25° and 59° N. (Clemens 1955). Since 1945 the majority of the fish have been caught in an area between Baja California and San Francisco within 400 miles of the coast, while between 1937 and 1945 large quantities were also taken off Oregon, Washington, and British Columbia. The year 1956 marked the return of the albacore to Pacific northwest waters after several years' virtual absence. Typically, the fishery begins in June off southern California, develops rapidly in July, reaches a peak in August and September, declines during October and November, and ends in December. Like the Japanese live-bait fishery, it is based on surface schools of albacore. The fish are taken by trolling and live-bait fishing. As the season progresses the fishery tends to move northward along the coast and also outward from the coast.

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[1] Van Campen, W. G. Manuscript. The Japanese Summer Albacore Fishery. Submitted for publication.

JAPANESE WINTER LONG-LINE FISHERY: This fishery is conducted between November and April over a broad area of the Temperate Zone of the North Pacific extending from the coast of Japan to the vicinity of 175° W. longitude generally between 30° and 40° N. latitude (Nakamura 1951, Suda 1954). The fishing ground gradually shifts southward as the season progresses, being centered between about 34° and 40° N. in November, and between 26° and 32° N. in March. This southward movement ceases in March and there is a reversal in the movement of the fishery beginning in April. The winter long-line fishery is terminated in April, and the live-bait fishery begins soon after.

The description of this fishery as well as that of the live-bait fishery are overly simplified versions of a more complex picture. Van Campen[1] pointed out that while Japanese writers often imply that all pole-and-line fishing is done in the spring and summer and all long-lining in winter, some albacore are taken by both methods in all months of the year.

OTHER JAPANESE FISHERIES FOR ALBACORE

Two relatively new fisheries, which yield significant amounts of albacore for the Japanese, are the mothership-type fishery and the so-called "foreign-based fishery," both of which exploit albacore along with other species of tunas in the tropical Pacific Ocean. Fishing is done by the long-line method. The mothership-type tuna operations began soon after World War II, while the fisheries based in foreign ports are of more recent origin.

MOTHERSHIP-TYPE FISHERY: The first large-scale commercial mothership-type tuna expedition in Japanese fisheries history was undertaken by the Taiyo Fishing Co., Ltd., in June 1950 following a directive issued by the Supreme Commander for the Allied Powers which permitted the Japanese to send expeditions to certain defined areas of the high seas adjacent to the Caroline, Marianas, and Marshall Islands. This expedition was composed of a 10,000-ton mothership and 25 long-line boats ("catchers"), which fished for a period of 2½ months. Details of this venture and several which followed, as well as the history of this type of operation in the Pacific, are presented by Shimada (1951), Ego and Otsu (1952), and Van Campen (1952). Such expeditions were authorized under the premise that fishing vessels operate only within a specified area, and under the rigid control and supervision of a mothership. That the Japanese found these large-scale ventures successful is attested to by the fact that they have been continued even after all restrictions on movements on the high seas were removed by the ratification of the Peace Treaty.

The announced plans for 1958 mothership operations involve three separate expeditions as follows: A 3,000-ton mothership and 23 catchers operating from May 20 through September 30, a 3,800-ton mothership and 35 catchers operating between May 10 and September 20, and an 11,000-ton mothership with 50 catchers operating in August and November.[2] These operations are reported to be similar in scope to the 1957 operations.

FOREIGN-BASED FISHERIES: At the present time there are two fisheries operating out of foreign ports in the Pacific; one at Espiritu Santo, New Hebrides, and the other at Pago Pago, American Samoa. No statistics are available for the operation based in New Hebrides; an enterprise reportedly involving American, British, and Japanese capital. According to information available, the fishing base was completed in November 1957, and operations were under way in July 1958 with about eight Japanese tuna long-line boats.

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[1] See page 2.
[2] *Fisheries Economic News*.

The fishery in American Samoa, a joint enterprise between a large United States west coast cannery and certain Japanese fishing firms, began in 1954 (Van Campen 1954). Starting with a small fleet of 7 Japanese tuna boats, this operation has expanded considerably, and today the American Samoa cannery is being served by a fleet numbering more than 30 long-liners. Albacore, along with other tunas and spearfishes, are landed throughout the year. There is no clear seasonal variation in albacore landings but the more productive months appear to be from August through February.

ALBACORE LANDINGS IN THE UNITED STATES AND JAPAN

Annual United States west coast and Japanese albacore landings are presented in figure 2. These and other statistics given in this article are in short tons. The source data are those cited by Van Campen.[1] The Japanese landings include fish taken by the two major fisheries as well as lesser amounts landed by independently-operating tuna long-liners from tropical waters of the Pacific and Indian Oceans. The statistics do not permit segregation of Pacific and Indian Ocean albacore landings. However, since most of the albacore are taken in Pacific waters, it is probably of little consequence to ignore the distinction, and perhaps even consider the Indian Ocean as a further extension of the Pacific grounds. There are certain irreconcilable discrepancies. Judging from the landings shown in figure 2 and the annual landings of the two major fisheries shown in figure 4, it appears that Japanese landings accounted for by other than the two major fisheries are included in the figures of total Japanese landings only for certain years. The figures as given by Japanese sources are presented without any adjustments.

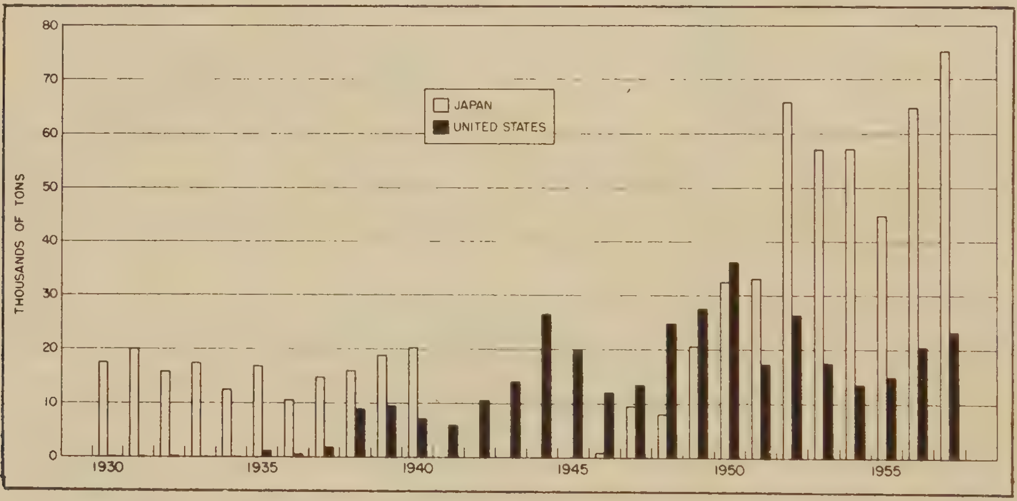

Fig. 2 - Japanese and United States west coast annual albacore landings, 1930-57.*
*The 1957 Japanese landings were obtained from statistics provided by the Nankai Regional Fisheries Research Laboratory, Japan.

The United States landings of albacore were at an extremely low level during the early 1930's. Albacore providied the major portion of the tuna pack from the beginning of the industry in California in 1903 to the early 1920's. There were average landings of about 9,000 tons a year between 1916 and 1925--the years for which statistics are available. Following a record year in 1925 when about 11,000 tons were landed, albacore suddenly failed to appear on the West Coast in its usual abundance. For the next 12 years the albacore catch was negligible in the United States. In waters off the Pacific Northwest, albacore showed up in commercial quantities for the first time in 1937, and a commercial pack was put up in Oregon and Washington in 1938 (Powell and Hildebrand 1950). This marked the beginning of a fishery in the Pacific Northwest which grew for several years and reached a peak in 1944 with landings of 17,000 tons. This fishery then declined until virtually no landings were made in 1952. In 1956 the albacore again returned in commercial quantities to waters off the Pacific Northwest.

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[1] See page 2.

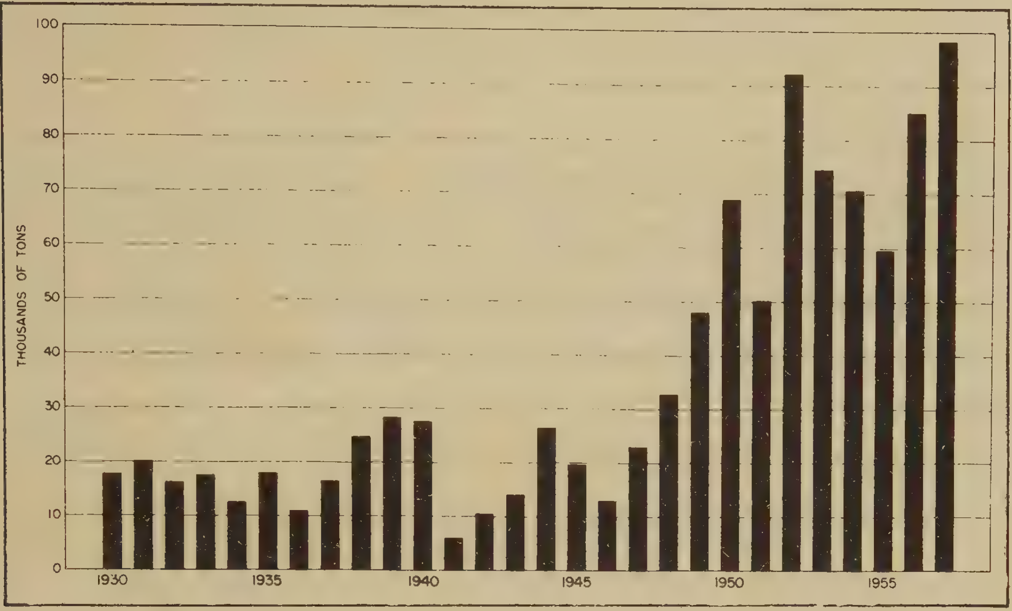

Fig. 3 - Total annual albacore landings (United States and Japan), 1930-57.

Following the recovery of the fishery around 1938, there have been some marked fluctuations in the landings from year to year, reaching relatively high levels in 1944 (26,000 tons) and in 1950 (36,000 tons). After peak landings in 1950, there was a gradual drop to a low of 13,500 tons in 1954. But in the last few years landings have again increased.

The Japanese began to export albacore to the United States in 1931 following the drastic drop in landings on the United States west coast. Prior to the establishment of this important export market, which has grown steadily over the years and has in recent years become a matter of serious concern to the United States fishing industry, Japanese fishermen had never sought this fish for domestic consumption (Van Campen[1/]). The albacore is considered too soft in texture, too pale in color, and even tasteless, by the Japanese who customarily eat tuna raw ("sashimi"). The export market, which developed in response to the failure of the California albacore fishery in the late 20's, has continued to grow because of the increasing demand in the United States for canned albacore which could not be supplied by United States landings alone.

Like most large commercial fisheries, the albacore fishery in the United States occasionally suffers serious setbacks due to economic difficulties. For example, Samson (1955) points out that had price disputes not hampered fishing in the middle of the 1955 season, albacore production that year could have been much greater because there apparently were unusually heavy runs of albacore at that time. However,

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[1/] See page 2.

it appears that in general the West Coast landings have fluctuated according to the availability of fish along the West Coast.

Japanese landings of albacore are also dependent upon economic considerations, to perhaps an even greater extent than the United States fishery. This situation is aggravated by the fact that nearly all albacore are exported. It has been reported that when an unfavorable export situation exists, and prices are low for albacore taken in the spring live-bait fishery, many of the boat owners are reluctant to go into winter long-lining for albacore, and may instead, turn their efforts toward fishing in the tropical Pacific or engage in some other fisheries such as that for mackerel (Anonymous 1958). In the live-bait fishery also, it is possible that when conditions are unfavorable many of the boats may continue fishing for skipjack rather than fish for albacore. It is not within the scope of this paper, however, to deal with the complex economic considerations.

The Japanese landings fluctuated little between 1930 and the onset of World War II, averaging a little over 16,000 tons a year (fig. 2). Fishing for albacore apparently continued for a few years after the start of the war but no statistics are available. Following the war there was a very rapid recovery, and by 1950 the production exceeded the prewar levels. The rapid development of this fishery can be seen more clearly if we examine the average landings for different periods. The 1930-35 landings averaged 16,706 tons a year, and during the 1936-40 period the average was 16,110 tons. After the war, from 1946 to 1950, the average dropped slightly to 14,344 tons. The average landings in the most recent period, 1951 to 1957, climbed to 56,771 tons, or more than three times those of prewar years.

In comparison with this increase in the level of landings, the United States landings increased at a far less spectacular rate. From an average of 5,562 tons a year in the 1936-40 period, during which there was a recovery from the virtual failure in the fishery, landings increased to an average of 22,755 tons a year during the postwar period of 1946-50. In the recent period, 1951-57, the average landings have been 18,976 tons, thus showing a slight decrease from the preceding period.

The combined yearly albacore landings of the United States and of Japan for 1930 to 1957 are shown in figure 3. With the exception of the war years, total landings of the two countries have shown a rather marked upward trend. From average annual landings of just under 17,000 tons in the 1930-35 period, the present level has reached approximately 76,000 tons (1951-57). This fourfold increase over the prewar period reflects the greatly increasing United States demand for canned tuna, of which albacore is the most highly prized.

That Japan is the leading producer of albacore is clearly seen in figure 2. Only during the war years and a few years following did the United States take the lead in total production. From 1951 to 1957, Japan accounted for an average of 75 percent of the total combined landings of the two countries.

TRENDS IN THE JAPANESE FISHERIES

TEMPERATE NORTH PACIFIC FISHERIES: Annual Japanese landings of the spring live-bait and winter long-line fisheries are compared in figure 4. Similar statistics are unavailable for 1938-1945. From 1931 through 1937 there was a steady decline in the landings of the live-bait fishery. The long-line fishery, on the other hand, showed some increase around 1935. This increase was due largely to a concerted effort made by the Japanese Government to compensate for the decline in pole-and-line catch by exploring grounds farther offshore beginning in 1933. The exploratory program resulted in an extension of the long-line grounds eastward. The landings correspondingly increased to a point where this fishery constituted the major source of albacore to the Japanese for a few years following.

In recent years the live-bait fishery has come to dominate tuna landings. Between 1951 and 1957, the live-bait fishery accounted for an average of 64 percent of the landings made by these two fisheries. This increased yield of the live-bait fishery has also been accompanied by an extension of grounds eastward, which was made possible by the addition of larger vessels in the fleet.

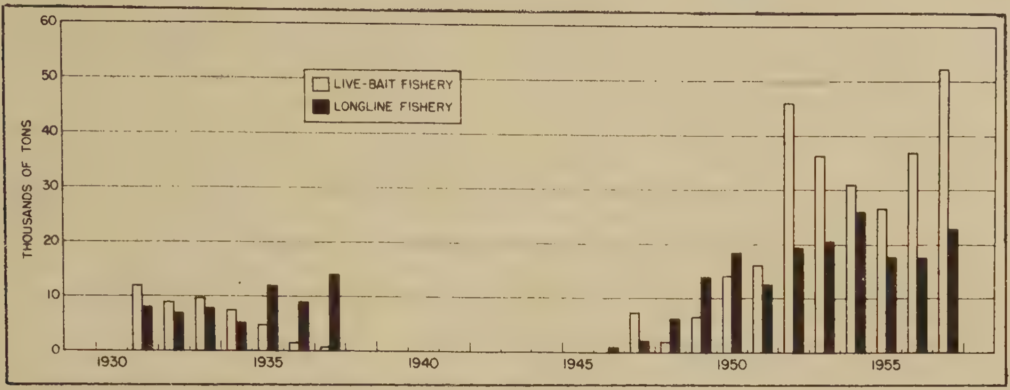

Fig. 4 - Comparison of the landings of the Japanese live-bait and long-line albacore fisheries. (Long-line landings do not include fish taken on mothership-type operations or by vessels based in foreign ports.)

The 1957 figures are estimated from monthly statistics provided by the Nankai Regional Fisheries Research Laboratory, Japan.

FISHERIES IN THE TROPICAL PACIFIC: For convenience in discussing the catch statistics of tropical albacore, two distinct fisheries have been described for the tropical Pacific, (1) the mothership-type fishery, and (2) the foreign-based fishery. In (1) the fishing vessels operate around a mothership using the latter as a base, and in (2) the vessels work out of a foreign land base. But there is little basis for considering these as separate fisheries. Both exploit subsurface tunas by the long-line method, and there are no clear seasonal or area differences that would make each distinct from the other.

While not given a special designation like the other fisheries, the numerous independent Japanese long-liners which ply the waters of the tropical Pacific and eastern Indian Oceans are nevertheless important contributors of long-line albacore. These vessels, capable of operating for considerable periods without logistic support of motherships or land bases, account for significant quantities of tropical tuna. Their contributions are reflected in the tremendous increase in over-all Japanese albacore landings (fig. 2).

The annual albacore landings by the mothership-type operations are given in table 1. For purposes of comparison the landings of yellowfin tuna (Neothunnus macropterus) are also shown.

Table 1 - Albacore and Yellowfin Landings of Japanese Mothership Fleets[1]

Year	Albacore	Yellowfin
	. . . (Short	Tons) . . .
1956	4,069	2,229
1955	5,409	3,221
1954	3,920	4,285
1953	321	4,794
1952	79	4,429
1951	137	5,432
1950	49	4,109

[1] 1957 figures are unavailable.
Sources: Annual Reports of Catch Statistics on Fishery and Agriculture, Statistics and Survey Division, Japanese Ministry of Agriculture and Forestry, 1955 edition; 1956 figures, source cited as the Japanese Fisheries Agency.

Yellowfin dominated the mothership landings during the first few years of operation, while albacore has become an important constituent only in more recent years. This is mainly a reflection of the shift in area of operations of the fleets, which during the period of restrictions exploited waters of the U. S. Trust Territory of the Pacific Islands, lying to the north of the Equator, where the predominant tuna species are the yellowfin and big-eyed (Parathunnus sibi) tunas. Probably because of the favorable acceptance of long-line caught albacore in the market, many of the fleets now operate in more southern waters, such as in the vicinity of Fiji and Tonga Islands, where albacore are found in great numbers. In 1955 and 1956, albacore landings outweighed yellowfin landings by 40 and 45 percent, respectively. Unquestionably there has been a shift in emphasis on the part of the Japanese toward a higher production of albacore in recent years.

Table 2 - Albacore and Yellowfin Landings of Japanese Foreign-Based Vessels

Year	Albacore	Yellowfin
	. . . (Short Tons) . . .	
1957	6,236	1,719
1956	3,781	2,159
1955	3,228	2,895
1954	270	638

Sources: 1954 and 1957 figures are from records of cannery in America Samoa. Weights of gilled and gutted yellowfin were roughly adjusted to round weights by adding 9 percent; 1955 and 1956 figures ascribed to Japanese Fisheries Agency.

Table 2 lists the annual landings of the foreign-based vessels. These are essentially landings of long-liners based in American Samoa since the New Hebrides operation did not begin until November 1957. The albacore and yellowfin are also the major tuna species taken by this fishery. Here again, a shift in dominant species is seen, similar to that shown by the mothership-type fishery.

In 1954 yellowfin was the predominant species, and albacore accounted for only 30 percent of the combined albacore and yellowfin landings. In 1955, albacore accounted for 53 percent; in 1956, 64 percent; and in 1957, 78 percent of the combined landings of these two species. Thus there has been a gradual tendency for albacore to figure more importantly in the Samoa catch each year since the inception of this fishery.

This shift has come about from a movement away from the old fishing grounds, which in 1954 and early 1955 were chiefly in the vicinity of Samoa and to the north. As vessels began working in more distant and southerly waters (e.g. Tonga Islands), catches of albacore increased noticeably. Today, more and more fishing is done in waters productive of albacore, a shift in emphasis which can be attributed largely to the good canning quality of these long-line caught tropical albacore and the higher price this species generally commands.

RELATIONSHIP OF ALBACORE TAKEN IN THE VARIOUS FISHERIES

At present little is known of the relationship of albacore found in different parts of the Pacific Ocean. As mentioned, the bulk of the Pacific albacore production is from the Temperate Zone of the North Pacific with Americans and Japanese conducting seasonal fisheries for the species. Available evidence from tag returns leads us to believe that there is a single population of albacore in the North Pacific (Blunt 1954, Ganssle and Clemens 1953, and Otsu MS[3/]). Albacore tagged off the United States west coast have been retaken off the coast of Japan, and those tagged in mid-ocean north of Hawaii have been retaken in the Japanese fishery as well as in the United States west coast fishery, thus showing that there is considerable movement of fish from one fishery to the other. The tag returns, therefore, support the contention that the Americans and Japanese are both exploiting a single, intermingling population of albacore in the Temperate Zone of the North Pacific.

Furthermore, examination of gonads of albacore from various areas has shown that the Temperate Zone North Pacific fish are without exception juveniles, or are sexually-immature adults which evince no signs of incipient or past spawning (Otsu and Uchida, in press). It appears then that the North Pacific albacore are but a segment of a much larger population which is ecologically separated into spawning and nonspawning components. This same study suggests that the spawning segment of the population occurs in tropical or subtropical waters. There may be a movement

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3/Otsu, T. Manuscript. Albacore Migration and Growth in the North Pacific Ocean as Estimated from Tag Recoveries. Prepared for publication in Pacific Science.

of the larger fish from Temperate Zone waters into subtropical waters, possibly into the North Equatorial Current area where some spawning appears to take place (Ueyanagi 1957, Otsu and Uchida, in press), or possibly farther south into the equatorial Pacific. It may be that these large fish spread out over a vast area in the tropical Pacific, or, as postulated by Suda (1956), the albacore occurring in the tropical South Pacific may comprise a spawning group of another population to be found in the southern hemisphere. The latter implies that the north Temperature Zone albacore is unrelated to the albacore of the tropical South Pacific now being exploited by the Japanese.

Obviously, there is much to be learned about the population structure of this valuable resource. While there does not appear to be any serious problems of overexploitation facing any of the Pacific albacore fisheries at the present time, a knowledge of the population structure would be of vital importance in formulating conservation or management policies should they prove to be necessary. If there are several discrete populations of albacore, the depletion of one would of course not affect a fishery based on another population. If however, the Americans and the Japanese are exploiting a single population of albacore in the North Pacific, then the problems concerning the resource would necessarily be of mutual concern. In this situation the effect of overexploitation would not be confined to whatever fishery is responsible, but would be shared by the other fishery as well. It is clear that the knowledge of the population structure constitutes a valuable adjunct to the understanding of problems inherent in these fisheries.

Although not well documented, frequent reference is made to the apparently close relationship between the major North Pacific albacore fisheries, that good and bad years appear at the same time in both the American and Japanese fisheries. If such a relationship does exist, it would be well worth noting because the American fishery follows the Japanese live-bait fishery in time, and the American industry is in a position to benefit by an advance indication of the relative magnitude of the season's landings.

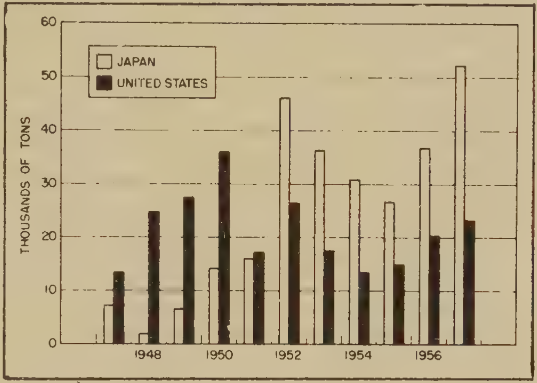

Fig. 5 - Comparison between the landings on the United States west coast and by the Japanese live-bait fisheries, 1947-57.

In figure 5, landings on the United States west coast and by the Japanese live-bait fisheries are compared. For the more recent years, after 1950, the landings show some corresponding trends. For example, 1952 was a particularly good year in both fisheries, and 1954 and 1955 were relatively poor in both. This apparent relationship breaks down if the earlier years are included.

From the point of view of fish sizes exploited by these two fisheries, with the American fishery taking smaller fish in general than the Japanese fishery (Otsu, T.[3]), it would appear more reasonable to expect correspondence in landings not on a year-to-year basis, but rather between year N in the American fishery and year N+1 or N+2 in the Japanese fishery if the fluctuations in annual landings are reflections of actual abundance. This assumes that availability factors remain the same from year to year, which of course is not entirely true for the albacore. While it is possible that an exceptionally good year in the Japanese fishery would be followed by a good season in the American fishery, or vice versa, there are probably other factors which affect the occurrence of fish in the two fisheries to such an extent that any clear relationship in the landings could not be expected.

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[3] See page 8.

DISCUSSION

It has not been possible to compile satisfactory statistics on fishing effort to be examined in relation to the gross landings statistics presented in this report. It is known that following the war the Japanese have continued to enlarge their fishing fleets, and have built larger vessels capable of fishing in more distant waters. A recent survey conducted by the United States Department of the Interior (Anonymous 1958) found that the number of Japanese fishing vessels had doubled since 1951. This expansion, although not applied to the albacore fishery alone, has nevertheless affected the catch of albacore, particularly in that portion of the landings accounted for by the numerous independently-operating long-liners fishing in distant tropical waters. While the Japanese have increased their fishing capacity with a view toward increased production, the situation on the United States west coast has been quite different. According to the same survey, the United States albacore fleet has been reduced from 3,000 to 1,000 boats in recent years. The general situation can perhaps be deduced from conditions prevailing in the tuna industry as a whole. According to Samson (1957), the 1957 California tuna clipper fleet (vessels over 50 gross tons) numbered only 146 as compared to the 1951 total of 210. Similarly, the tuna purse-seine fleet underwent a drastic reduction of from 163 vessels in 1947 to 58 by the end of 1957.

The available data on fishing effort do not permit a detailed analysis of the effect of effort on the level of landings. Judging from gross catch statistics alone, it might be reasonable to deduce, however, that there was perhaps a parallel increase in catch with increasing effort in the Japanese fishery. The fact that their present landings are triple those of prewar years attests to this. It is of course possible that the catch has not kept pace with effort, and that there is a general leveling off of catch relative to the rising effort. It is not possible to determine this without detailed data on effort, but in the face of the continued high level of production in the last several years, it seems unlikely that exploitation has seriously affected the albacore stock.

While it is true that the Japanese have had to build larger vessels and go farther from Japan in order to meet their catch goals, it must be realized that the present level of albacore landings is significantly higher than the prewar level. Their two North Pacific fisheries appear to be quite stable, even at the present high level of catch. There is no indication of a declining resource. While the South Pacific fisheries are relatively recent in origin and may not have stood the test of time, the present status of the Samoa-based fishery or the mothership operations is encouraging as far as albacore catch is concerned.

Catch statistics, although not reliable when considered alone, indicate that the albacore resources in the Pacific are extensive, and that production can probably be increased particularly by exploitation of new grounds, as shown by the Japanese in the South Pacific. In the absence of catch per unit-of-effort data it is not possible to evaluate the situation in the present North Pacific grounds with any degree of confidence. While the annual fluctuations in the landings of these fisheries from "good" through "poor" years may possibly indicate that much heavier exploitation will not substantially increase production, it also appears unlikely that these fisheries are being overexploited at present. All indications on the present status of the albacore fisheries point to a parallel rise in effort and catch through a background of erratic natural fluctuations.

SUMMARY

1. Catch statistics are presented for the major Pacific albacore fisheries which include: (1) the United States west coast summer to fall fishery, (2) Japanese winter midocean long-line fishery, (3) Japanese western Pacific spring to summer live-bait

fishery, (4) Japanese tropical Pacific mothership fishery, (5) Japanese tropical Pacific foreign-based fishery.

2. The American fishery has been beset with marked fluctuations in production. With the establishment of the canning industry in California in 1903, albacore landings increased until 1925 when the species suddenly failed to appear on the west coast in its usual abundance. Landings were negligible until around 1938. In the last decade, the landings have shown a downward trend following the peak year of 1950 with 36,000 tons until 1954 when approximately 13,500 tons were landed. The last few years again showed a trend toward greater catches.

3. The Japanese landings of albacore, which averaged a little over 16,000 tons a year between 1930 and the onset of World War II, have in recent years increased to an average of more than 55,000 tons (1951 to 1957), or more than three times those of prewar years. This tremendous increase reflects the increasing demand in the United States for canned albacore, since the bulk of the Japanese landings are exported to the United States for that purpose.

4. Japan accounts for an average of 75 percent of the combined albacore catch of the two countries, United States and Japan.

5. Of the several Japanese fisheries for albacore described, the two oldest, and also the most important, are the winter long-line and the spring-summer live-bait fisheries. Both of these fisheries are conducted in the Temperate Zone of the North Pacific. The live-bait fishery is the leading source of Japanese albacore.

6. The tropical fisheries are relatively recent in origin. Two distinct tropical fisheries, the mothership and the foreign-based, are described. There is a third category, not considered in this report due to lack of separate statistics, and this is the group of independent Japanese tuna long-liners which operate in tropical waters without benefit of either a mothership or a foreign base. These vessels undoubtedly account for significant quantities of albacore. In the tropics all albacore are taken by the long-line method, and seasons are not clearly defined as in the Temperate Zone North Pacific fisheries. It is shown that albacore has come to figure more prominently in the landings of these fisheries in recent years, and this is believed due to a purposeful shift in species emphasis.

7. Since frequent reference is made to the apparently close relationship between the American and Japanese fisheries, that good and bad years appear at the same time in both fisheries, the landings of the American fishery were compared with landings of the Japanese live-bait fishery. A relationship as alluded to is not clearly evident.

8. Although detailed data on albacore fishing effort are not available, the general situation prevailing in the tuna industries of the two countries may be indicative of any general trends. This shows that the Japanese have been building larger vessels and have continued to enlarge their fishing fleet ever since the end of World War II. In addition, they have expanded their fishing grounds to include more distant waters. Along with this increasing effort, there was a parallel rise in the level of albacore landings. The situation is apparently quite different in the American albacore fishery and it is unlikely that there was any increase in fishing effort over the last few years.

9. Catch statistics of the various albacore fisheries show no evidence that exploitation has had any detrimental effect on the albacore stock. There appears to have been a parallel rise in effort and catch through a background of erratic natural fluctuations.

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AGE DETERMINATION OF ALBACORE BY THE VERTEBRAL METHOD

by
Tamio Otsu and Richard N. Uchida
Pacific Oceanic Fishery Investigations, Honolulu, T.H.

ABSTRACT

An attempt was made to determine the age of central North Pacific and Hawaiian Albacore, *Germo alalunga* (Bonnaterre), by counting rings in the vertebral centra, a method or which some degree of success had been reported elsewhere. Results were negative ecause of the impossibility of duplicating counts in successive readings or by different eaders. It is concluded that the Albacore from these areas cannot be aged by the vertebral nethod with presently existing techniques.

INTRODUCTION

This is a preliminary report on a study determine the age and growth of Albacore, *mo alalunga* (Bonnaterre), taken from the ers of the Hawaiian Islands and from the th Pacific Ocean north and northwest of waii. This study is part of the Albacore earch program presently being conducted the Pacific Oceanic Fishery Investigations FI) of the U.S. Fish and Wildlife Service ler Public Laws 329 (80th Congress) and (Saltonstall-Kennedy Act, 82nd Congress).

Several workers in the past have reported the age and growth of Albacore as determined m examination of the surface marking on the tebral centra. Aikawa and Kato (1938) based ir studies on 10 large Albacore taken near dway Islands and five small fish taken off theastern Japan. Partlo (1955) made a more nprehensive study based on vertebrae of fish taken during the 1950 fishing season m the offshore waters of California, Oregon, shington, and British Columbia. Figueras 55) followed with a brief report based on specimens taken off the coast of Galicia rthwestern Spain). Uno (1936a, b), without ing details of his technique, reported on results of his study based on about a usand fish taken off the Japanese coast.

All of these workers either directly or lirectly suggested the presence of rings on inner surfaces of the two hollow cones the amphicoelous Albacore vertebra. They ncluded that each ring represented an annulus d, therefore, the number of rings was an licator of age. By measuring the distance m the centre of the centrum to each ring, ey believed they were deriving an estimate of the growth of the fish. Aikawa and Kato, Figueras, and Uno, as far as we can determine, have provided no evidence showing that the rings on the vertebrae are indeed "age rings" and annual in nature. Partlo hypothesized that the rings are true year marks by the following: (1) by assuming that the length groups in the size frequencies are age groups, he found that there was acceptable agreement between the mean length of fish assigned to each vertebral ring-class and the mean length of corresponding length-groups in the sample, and (2) there was agreement between the lengths of young fish calculated from vertebral measurements of older fish and the observed lengths of young fish. For the latter, Partlo, working with a subsample of 98 fish, found that the observed lengths were consistently greater than the calculated lengths because the fish were captured some time after the last ring was formed. Partlo concluded that "from the above it seems clear that the third and subseguent vertebral rings are produced annually. It is assumed, in the absence of contrary evidence, that the inner two rings are annual also."

In our study we attempted to evaluate the use of vertebrae to determine the age of Albacore taken in the North Pacific and in Hawaiian waters. Employing a wider size range of fish than had hitherto been used by any single worker, we hoped to extend previous findings to include the large fish landed in the Hawaiian Islands, and at the same time make a careful examination of the evidence appearing to indicate that the rings on the centra are true year marks. However, as will be shown, we were not able to duplicate or verify past results, nor did we find that we could use the vertebrae to age central North Pacific and

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CONCLUSIONS

Although vertebrae of small Albacore were somewhat more "readable" than those of the larger Albacore, we were unable to achieve sufficient consistency in our readings and measurements to validate this method of age determination. It appears that the Hawaiian Islands and central North Pacific Albacore cannot be aged by the vertebral method with presently existing techniques.

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EXUAL MATURITY AND SPAWNING F ALBACORE IN THE PACIFIC OCEAN

BY TAMIO OTSU AND RICHARD N. UCHIDA

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FISH AND WILDLIFE SERVICE, Arnie J. Suomela, *Commissioner*

EXUAL MATURITY AND SPAWNING F ALBACORE IN THE PACIFIC OCEAN

BY TAMIO OTSU AND RICHARD N. UCHIDA

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ABSTRACT

This report presents the results of a study of gonadal development and spawning in the albacore, *Germo alalunga* (Bonnaterre). The study is based on examination of the reproductive organs, principally the ovaries from albacore collected in three general areas: the North Pacific, the Hawaiian Islands, and the central equatorial Pacific.

The ovaries were classified in three stages of relative maturity: early developing, late developing, and advanced, on the basis of the most advanced eggs present. According to this classification, the early developing category included the thin ribbonlike ovaries from sexually immature fish as well as ovaries from the larger, adult fish which showed no signs of egg development beyond this particular stage. The other two categories, on the other hand, included only ovaries from adult fish.

The North Pacific albacore were either juveniles or sexually dormant adults with early developing gonads. The Hawaiian albacore showed varying degrees of maturity from early developing to advanced, with the bulk of the ovaries in the late developing stage. The ovaries from central equatorial Pacific fish were in the early developing and late developing stages, with the early developing stage predominating.

Our data show that albacore taken north of Hawaii by research vessels of the Pacific Oceanic Fishery Investigations, as well as albacore taken by the Japanese in the spring live-bait and winter longline fisheries, and those in the American west coast summer fishery are nonspawning fish, either juveniles or adult fish whose gonads show no signs of incipient or past spawning. Albacore apparently do not spawn in the temperate waters of the North Pacific. On the other hand, it appears that the albacore in the region of the Hawaiian Islands and in the central equatorial Pacific represent a segment of the population which, after attaining a certain size in temperate waters of the North Pacific, moves south into tropical and subtropical waters to reproduce.

SEXUAL MATURITY AND SPAWNING OF ALBACORE IN THE PACIFIC OCEAN

By **Tamio Otsu** and **Richard N. Uchida**, *Fishery Research Biologists, Bureau of Commercial Fisheries*

e albacore, *Germo alalunga* (Bonnaterre), is nmercially important tuna, valued highly for cellent canning qualities. In the Pacific the r fisheries for this species are conducted by apanese in an area extending from the coast pan to the vicinity of the International Date and by the Americans along the west coast ne United States. Tag recoveries during t years have shown that albacore undertake sive migrations across the Pacific (Ganssle Clemens 1953, Blunt 1954, Otsu and Uchida , thus suggesting that these major fisheries be dependent on a single population.

bacore are also widely distributed throughout ropical Pacific, but in this region they are rally taken incidental to the catch of other es of tuna. It is not known whether albacore e tropics belong to the same population as of temperate latitudes, or whether they form of another population. According to present vledge, albacore do not spawn in temperate rs. Information on the areas of spawning t provide a clue to the general distribution of populations that support the American and nese albacore fisheries.

e research program of the Pacific Oceanic ery Investigations (POFI) of the Bureau of mercial Fisheries has included a study of gon- development and spawning in the albacore, h has been financed by the Saltonstall-Ken- Act (Public Law 466, 83rd Congress). The nt report on the albacore is based on examina- of the reproductive organs, principally the ies, collected in three general areas: the North fic, the Hawaiian Islands, and the central torial Pacific. Important differences in gonad lopment were noted for fish from these three s. The size at which albacore attain sexual rity was determined, and what appears to be jor spawning locality can now be defined.

We gratefully acknowledge the contributions of the following persons: R. S. Shomura and B. Wyatt who collected ovaries at the Honolulu auction markets; the managements of the United Fishing Agency, Ltd., and the Hawaii Fishing Co., Ltd., and the several fish dealers who permitted us to sample the albacore landings; Shoji Ueyanagi of the Nankai Regional Fisheries Research Laboratory in Kochi, Japan, who sent us samples of ovaries; and H. S. H. Yuen for valuable suggestions pertaining to sampling procedure.

SOURCE OF MATERIALS

NORTH PACIFIC

A total of 126 gonads from both sexes was collected between January 1955 and November 1956 in the North Pacific on POFI's exploratory fishing cruises (table 1 and fig. 1). Most of the sampled fish, ranging in length from 50 to 112 cm. (weight, 6 to 65 lbs.), were taken at the surface by gill nets or trolling; the few albacore larger than 87 cm. were taken exclusively on longline

TABLE 1.—*The number of albacore gonads obtained in the three areas [1] in various years*

Month	North Pacific				Hawaii		Central Equatorial Pacific			
	1955		1956		1955	1956	1952	1953	1956	1957
	Male	Female	Male	Female						
January	4	5	0	0	0	0	0	0	0	3
February	2	1	0	0	0	0	2	11	0	8
March	0	0	1	1	0	0	1	3	0	0
April	0	0	0	4	0	0	0	0	0	0
May	0	0	0	0	2	0	0	22	0	0
June	0	0	0	0	18	2	0	0	0	0
July	0	0	5	6	5	9	0	0	0	0
August	4	9	10	12	5	1	0	1	1	0
September	2	0	0	1	1	7	0	0	7	0
October	6	5	3	3	1	1	1	0	0	0
November	0	0	24	18	0	4	6	0	0	0
December	0	0	0	0	0	0	0	0	0	0
Total	18	20	43	45	32	24	10	37	8	11

[1] Fish of both sexes were sampled in the North Pacific but only females in the other two areas.

E.—Approved for publication January 13, 1958. Fishery Bulletin 148.

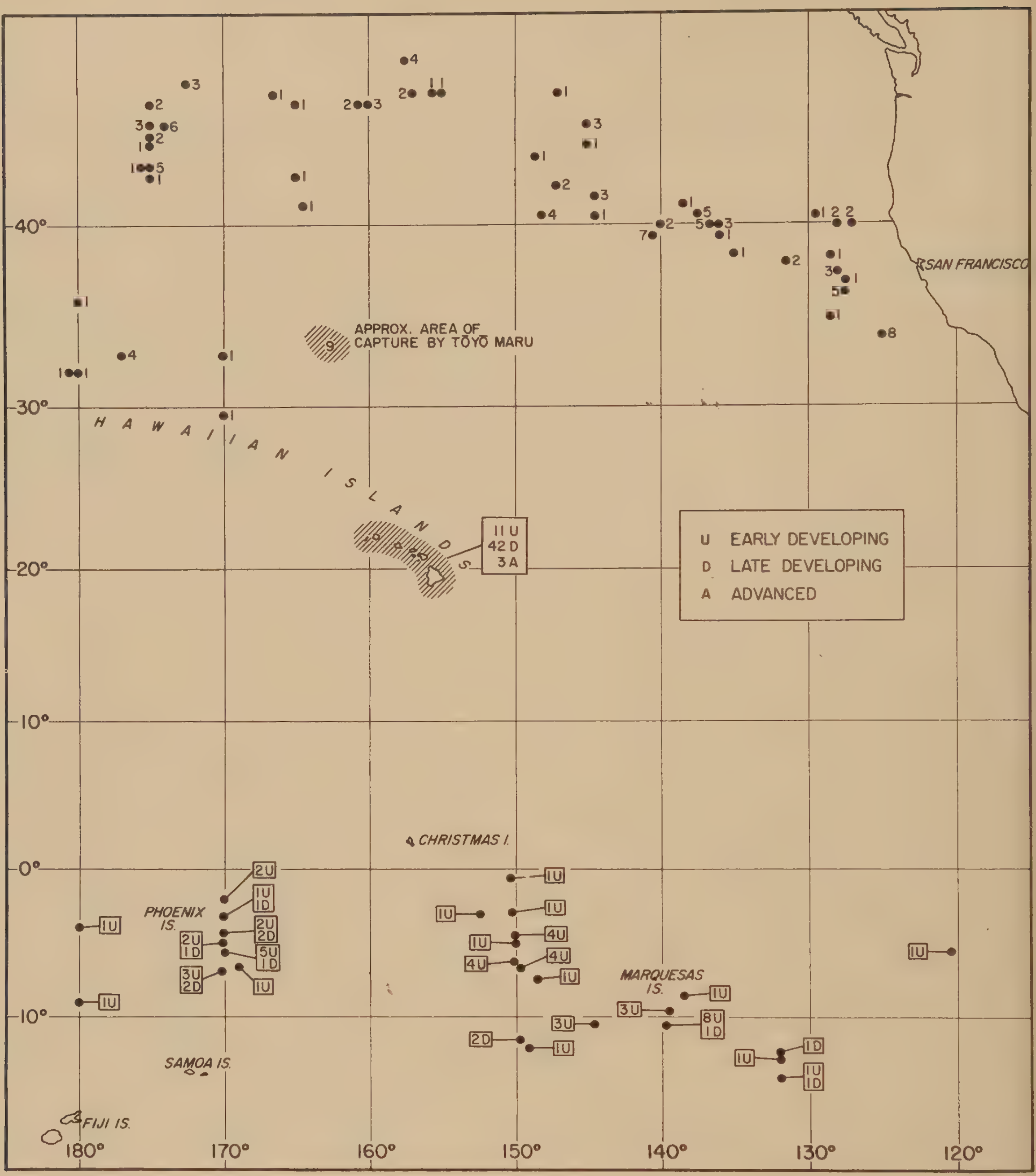

40°
30°
20°
10°
0°
10°
180°
170°
160°
150°
140°
130°
120°
HAWAIIAN ISLANDS
APPROX. AREA OF CAPTURE BY TŌYŌ MARU
SAN FRANCISCO
U EARLY DEVELOPING
D LATE DEVELOPING
A ADVANCED
11 U
42 D
3 A
CHRISTMAS I.
PHOENIX IS.
MARQUESAS IS.
SAMOA IS.
FIJI IS.

FIGURE 1.—Localities at which albacore gonads were collected. The Hawaiian and central equatorial Pacific sa consisted only of ovaries (stages of development shown); the North Pacific samples included testes and ovari of which were in the early developing stage. (U=early developing, D=late developing, A=advanced stag

(fig. 2). Immediately after the fish were landed the gonads were removed and preserved in 10-percent formalin. Data recorded were the date and locality of capture, fork length (weight was not always recorded), and the type of fishing gear.

In addition to the albacore taken on POFI ve we examined ovaries from a catch of alb landed in Honolulu by a Japanese longline v the *Tōyō Maru*, in January 1955. This reportedly obtained her catch northwest o

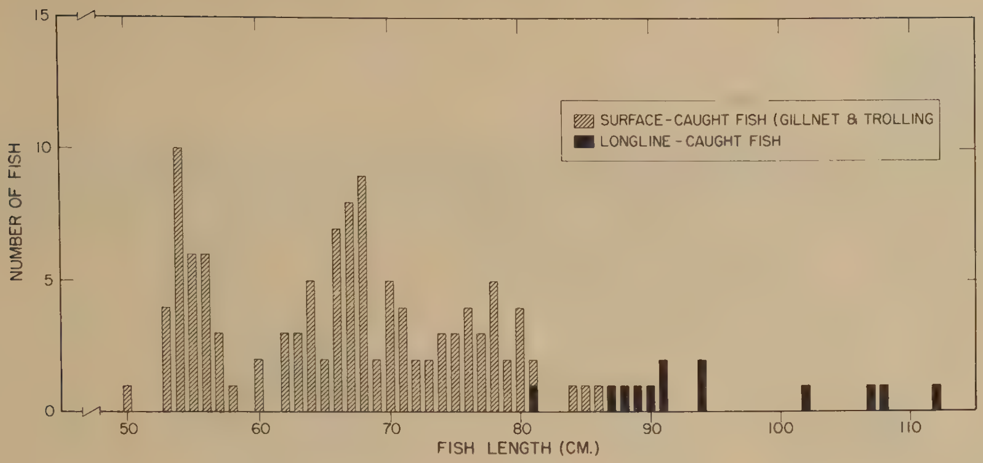


FIGURE 2.—Sizes of albacore sampled in the North Pacific.

aiian Islands in the general area shown in e 1.

HAWAIIAN ISLANDS

varies from 56 fish ranging in length from 93.1 .2.4 cm. (weight, 33 to 62 lbs.) were obtained 955 and 1956 from landings of the Hawaiian ine fishery (table 1, fig. 1). These fish were ured within 20 miles of the main Hawaiian nds, mostly during the months of June to ember. A detailed description of this fishery ven by June (1950) and Otsu (1954). These core and those taken by the *Tōyō Maru* were pled at the auction markets of the United ing Agency, Ltd., and the Hawaii Fishing Co., , both in Honolulu. The ovaries were preed in 10-percent formalin. Data obtained for fish were the date of landing, locality of ure, fork length, and weight.

CENTRAL EQUATORIAL PACIFIC

he bulk of the samples from the central torial Pacific was obtained from three areas: between the Equator and 7° S. latitude along ° W. longitude; (2) between the Equator and S. along 150° W. longitude; and (3) from the eral region of the Marquesas Islands, 132° W. 40° W. longitude (table 1, fig. 1). A total of female albacore, all captured on longline on FI cruises, was sampled between February 2 and February 1957; these fish ranged in th from 84.6 to 104.8 cm. (weight, 29 to 54). In general, sampling in this area was radic both in space and in time. The method sampling the ovaries was similar to that described for the collection of gonads in the North Pacific.

DESCRIPTION OF THE GONADS

TESTES

The testes are paired, elongate organs suspended by the mesorchium in the body cavity. They are thin and ribbonlike in immature fish but with advance in maturity, they develop into somewhat flattened, whitish-yellow organs which are relatively solid. Their products are collected by a series of small ducts, vasa efferentia, leading posteriorly to a larger duct, the vas deferens, which opens to the exterior through the urogenital orifice.

June (1953) examined both the testes and ovaries in his study of the spawning of yellowfin tuna in Hawaiian waters but found that for this study "the testes were not suitable because no quantitative measure of their sexual products could be found that would provide reasonably accurate estimates of their relative stages of development." We found this to be true for the albacore also, and the testes were therefore merely designated in this report as immature or mature on the basis of their size and the presence or absence of milt.

OVARIES

The ovaries, like the testes, are paired, elongate organs suspended from the dorsal wall of the body cavity by the mesovarium. In immature fish, the ovaries are ribbonlike (fig. 3), may measure as little as 2 or 3 millimeters in diameter, and closely resemble the immature testes in appearance.

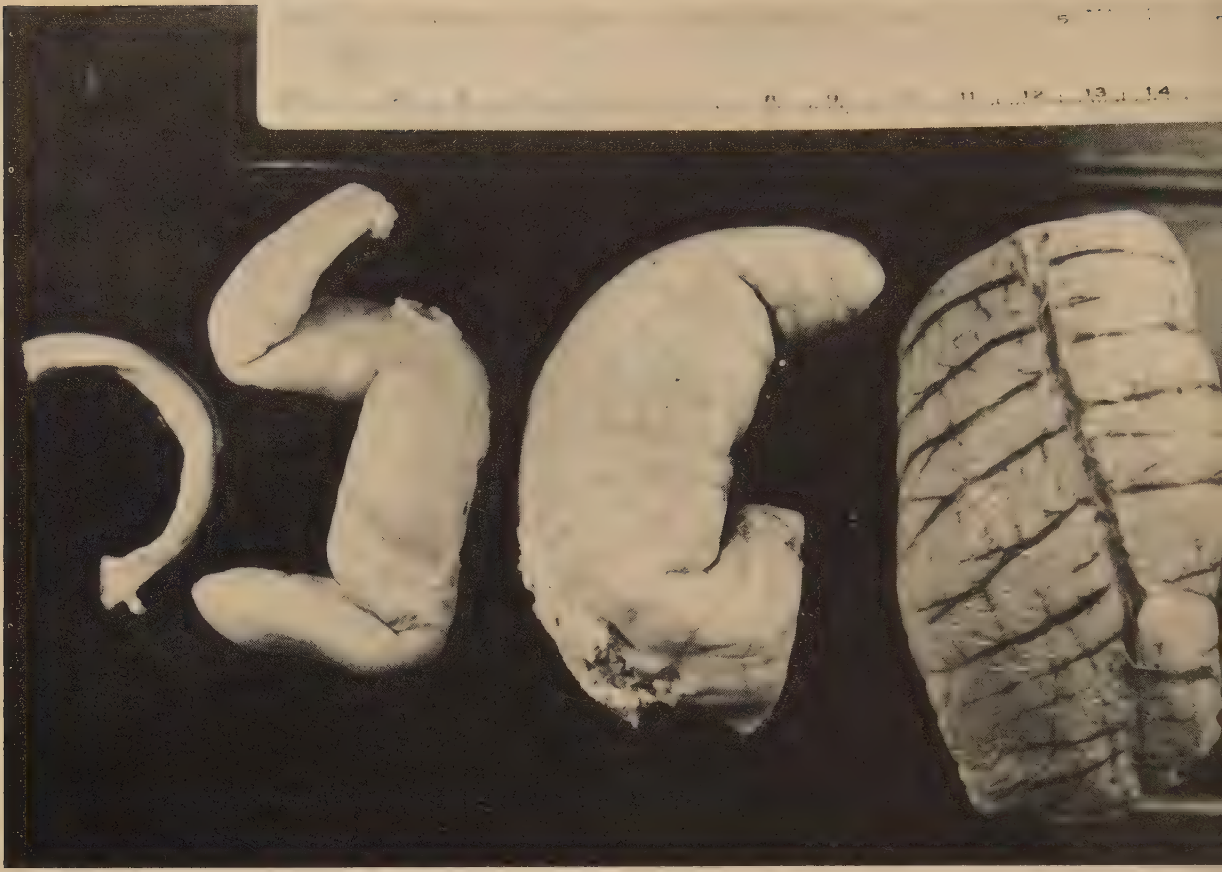


FIGURE 3.—Albacore ovaries in various developmental stages (only part of each ovary is shown). Left to right: a rib like ovary taken from a sexually immature, 75.8-cm. fish (ovary weight 9 grams); an early developing ovary fr 99.2-cm. fish (ovary weight 74 gms.); a late developing ovary from a 98. 5-cm. fish (ovary weight 275 gms.); ar advanced ovary from a 107.6-cm. fish (ovary weight 916 gms.). Photograph by H. Yoshida.

They become progressively enlarged in length and girth as the fish attain sexual maturity, and with the final ripening of the eggs, they may attain a diameter of more than 40 mm. In the more advanced stages, the ovaries are nearly circular in cross section and the right ovary is usually slightly larger than the left. They have a ribbed internal cavity throughout their length and unite posteriorly with a thick-walled oviduct which opens exteriorly through the urogenital orifice.

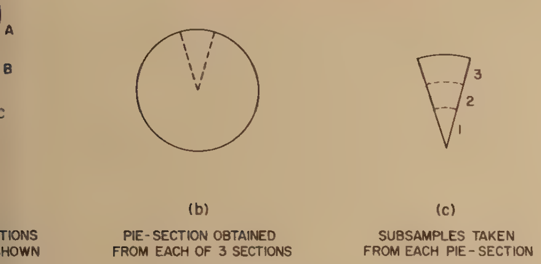
SUBSAMPLING THE OVARY

An objective method for determining the degree of maturity of an ovary is to measure the diameters of the constituent eggs. In order to reduce the amount of work involved in measuring the tremendous number of eggs within an ovary, it was necessary in our study to resort to subsampling. To subsample an ovary with confidence, however, requires that the distribution of eggs of var sizes throughout an ovary as well as differe between the two ovaries of a pair be determi

The procedure followed in this study wa general similar to that described by Yuen (1 who investigated the maturity and fecundit the bigeye tuna in the Pacific. Eggs fro sample were measured in a Sedgewick-R counting chamber ruled with parallel guide l The parallel lines prevented duplicate meas ments of the same egg. Measurements made to the nearest micrometer unit (0.0167 n using an ocular micrometer. Because the fo lin-preserved eggs of the albacore are not perfe spherical, we adopted the method of Clark (1 June (1953), Yuen (1955), and others of measu the random diameter parallel to the ruled lin the counting chamber in whatever axis the lies.

RIBUTION OF MATURE EGGS WITHIN AN OVARY

ral tests were conducted to evaluate ng procedures. First, it was thought neces-) determine whether advanced eggs were distributed within an ovary. For this hin cross sections were taken from the r, middle, and posterior parts of the right r of one of the most advanced ovaries in the on (fig. 4a). The cross sections were


A
B
C
(b)
(c)
3
2
1
TIONS
HOWN
PIE-SECTION OBTAINED FROM EACH OF 3 SECTIONS
SUBSAMPLES TAKEN FROM EACH PIE-SECTION

4.—Schematic representation of method used to n test samples for determining most efficient sam- procedure.

l A, B, and C, respectively. A triangular 1 was then obtained from each of the three sections (fig. 4b). Each triangular section urther subdivided into three subsamples enting, respectively, the center, mid-region, eriphery of the ovary (fig. 4c). Thus, for 1 A there were positions A_1, A_2, and A_3; for 1 B, positions B_1, B_2, and B_3; and for section itions C_1, C_2, and C_3. These samples were ed to the nearest 0.001 gram. All of the 1 the most mature group were then measured. eights and measurements are given in table 2. analysis of variance (table 3) indicated a cant difference ($P<0.05$) between positions e mean egg diameters but none between ns. The diameter means for sections A, B, were 0.842 mm., 0.848 mm., and 0.842 mm., tively. The results showed that for sec- A and B, the mean egg diameter was largest periphery of the ovary. The situation was ed for section C where the mean diameter east at the periphery and greatest near the l lumen (table 2). It has not been deter- l whether the differences between positions al or an artifact of preservation.

e number of eggs in the most advanced group expected from 0.1 gram of each sample was then calculated from table 2 and tested by analysis of variance (table 4). The results showed that there was no significant difference ($P>0.05$) in the relative numbers per unit weight of ovary between sections A, B, and C.

TABLE 2.—*Frequency distributions of diameters of the most advanced group of eggs from the various parts of an ovary (albacore No. 42—Hawaii)*

Diameter (in millimeters)	Sample No.								
	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3
0.668	0	0	0	0	0	0	0	0	1
.685	0	1	0	1	0	0	0	1	1
.701	2	3	2	1	1	0	1	0	2
.718	1	4	4	1	0	1	2	1	2
.735	0	0	4	1	1	0	2	3	4
.752	1	7	3	1	1	1	2	8	9
.768	5	16	5	2	5	1	6	12	12
.785	11	13	10	5	2	1	7	13	10
.802	14	16	15	6	10	7	9	17	13
.818	14	16	15	9	9	4	12	11	14
.835	23	18	23	12	14	6	22	28	22
.852	13	22	13	15	14	7	23	14	19
.868	15	14	16	10	13	16	20	16	17
.885	10	18	9	12	7	5	13	10	12
.902	1	8	13	3	5	1	11	12	5
.918	2	11	8	1	6	3	6	6	6
.935	2	3	7	1	2	4	4	3	6
.952	1	3	5	2	2	2	3	4	0
.969	1	3	6	1	2	0	2	4	3
.985	0	2	1	0	0	1	1	1	3
1.000	0	1	2	0	0	0	1	0	2
Sum	116	179	161	84	94	60	147	164	163
Mean diameter (mm.)	0. 833	0. 838	0. 850	0. 842	0. 848	0. 858	0. 850	0. 838	0. 837
Sample weight (gms.)	. 053	. 088	. 080	. 039	. 047	. 034	. 088	. 078	. 070

A comparison was made of the egg-diameter frequencies of the right and left ovaries (albacore No. 74, Hawaii). A random sample was obtained from the central section of each ovary and all eggs larger than 10-micrometer units (0.167 mm.) were measured (table 5). The comparison resulted in a chi-square of 19.77 ($P=0.9$, 30 $d.\ f.$[1]) indicating a general similarity in the distributions between the two ovaries.

The results of the various tests suggested that representative samples of an ovary could be obtained anywhere along its length, provided a

TABLE 3.—*Analysis of variance of diameters of the most advanced eggs from different parts of the ovary (albacore No. 42, Hawaii)*

Source of variation	Degrees of free-dom	Sum of squares	Mean square
Between sections	2	40. 53	20. 27
Positions within sections	6	165. 85	*27. 64
Individuals within positions	1, 159	13, 770. 45	11. 88
Total	1, 167	13, 976. 83	

*Indicate significant ($p<0.05$) mean square value.

---

[1] The last four classes in the frequency distributions were combined because of the low numbers.

random subsample was obtained from the cross section. It was also shown that either of the two ovaries could be used. The procedure routinely used was to measure a random subsample from the mid-section of an ovary.

TABLE 4.—*Analysis of variance of numbers of most advanced eggs from different parts of the ovary (albacore No. 42, Hawaii)*

Source of variation	Degrees of freedom	Sum of squares	Mean square
Between sections	2	156. 24	78. 12
Positions within sections	6	3, 152. 96	525. 49
Total	8	3, 309. 20	

TABLE 5.—*Egg diameter frequencies of right and left ovaries from the same fish (albacore No. 74, Hawaii)*

Diameter		Frequency	
Micrometer units [1]	Mm.	Right ovary	Left ovary
10	0. 167	259	282
11	. 184	137	147
12	. 200	124	122
13	. 217	117	101
14	. 234	107	108
15	. 250	115	93
16	. 267	82	71
17	. 284	72	64
18	. 301	75	75
19	. 317	69	64
20	. 334	51	51
21	. 351	48	44
22	. 367	54	43
23	. 384	56	55
24	. 401	45	51
25	. 418	59	46
26	. 434	40	32
27	. 451	39	30
28	. 468	47	32
29	. 484	29	32
30	. 501	32	33
31	. 518	16	19
32	. 534	15	21
33	. 551	26	32
34	. 568	27	29
35	. 584	27	28
36	. 601	18	25
37	. 618	20	19
38	. 635	19	13
39	. 651	10	8
40	. 668	6	4
41	. 685	2	1
42	. 701	3	1
43	. 718	1	0
Sum		1, 847	1, 776

[1] 1 micrometer unit = .0167 mm.

DEVELOPMENTAL STAGES OF THE EGG

Eggs were classified as early developing, late developing, and advanced. The descriptions are based on formalin-preserved material.

Early Developing

This category includes the primitive eggs found in all ovaries and eggs in the beginning stages of development. The primitive eggs vary from about 0.01 to 0.13 mm. in diameter, possess relatively large nuclei, and are transparent
early development the eggs increase in siz
become semi-opaque from deposition of
granules. The maximum diameter of eggs i
early developing stage is about 0.4 mm.

Late Developing

In this stage, the eggs are completely o
from the heavy accumulation of yolk gra
They now range from 0.4 to about 0.8 m
diameter.

Advanced

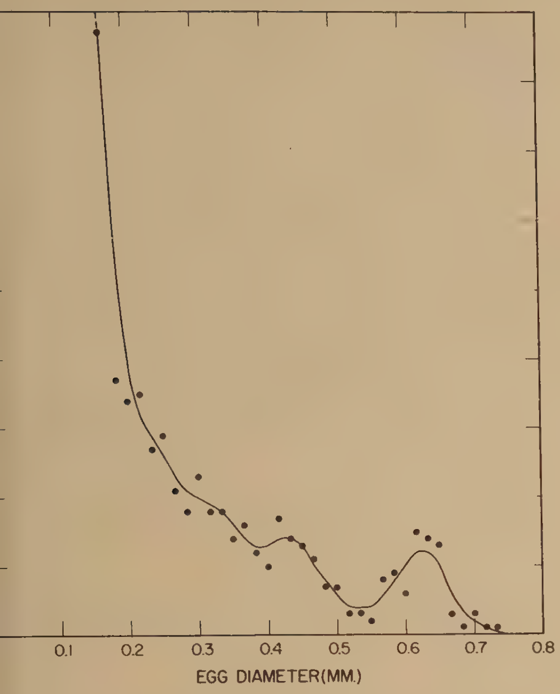
Distinct changes occur in the eggs as
approach ripeness. They lose their opacity
become semitransparent; the nucleus cann
detected at this stage, and a conspicuous g
yellow oil globule appears. These advance
not fully ripe eggs range from about 0.7 t
mm. in diameter in the most advanced s
available for study.

CLASSIFICATION OF OVARIES

The ovaries were classified into three c
ries of relative maturity, early developing
developing, and advanced, according to the
of development of the largest eggs. In this
fication, the early developing category inc
the thin ribbonlike ovaries from sexually i
ture fish and ovaries from the larger adul
which showed no signs of egg development b
the early stage. The other two categorie
the other hand, included only ovaries from
fish (fig. 3).

As an example of the classification, a freq
distribution of egg diameters from a fish c
as having late developing ovaries (fig. 5) is s
In addition to the mode of largest eggs cen
at 0.63 mm., other groups of eggs are ev
There are large numbers of early developin
less than 0.4 mm. in diameter, and there i
dence of a second group of late developing
one with a mode at 0.43 mm. Both grou
late developing eggs were opaque, charact
of this stage.

An advanced ovary (fig. 6) has a mode of
transparent eggs centering at about 0.86 mm
addition there is one or more groups of la
veloping eggs between 0.4 and 0.6 mm., poss
less developed group at about 0.33 mm., as
the usual large numbers of early developin



E 5.—Frequency curve of 550 egg diameters meas- from a late developing ovary of a 55-pound albacore n in Hawaiian waters on June 15, 1955. The curve derived by smoothing the data twice by a moving age of three.

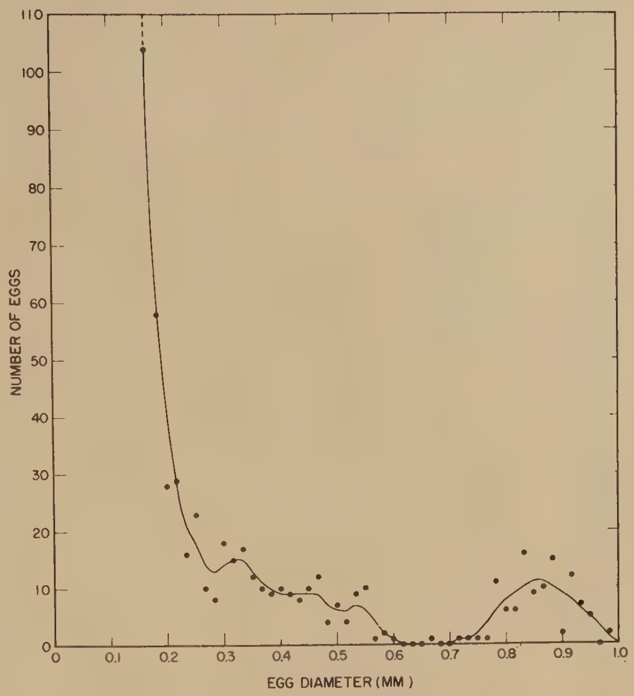


FIGURE 6.—Frequency curve of 550 egg diameters measured from an advanced ovary of a 47-pound albacore taken in Hawaiian waters on June 8, 1955. The curve was derived by smoothing the data twice by a moving average of three.

ESULTS OF GONAD EXAMINATION

NORTH PACIFIC

ce the gonads of albacore in the North Pacific enerally thin and ribbonlike (early develop- the sexes are often difficult to distinguish by examination in the field. For this reason, ds of both sexes were collected and the sex letermined in the laboratory by microscopical ination. Of the gonads of 126 fish examined, ere ovaries and 64 were testes.

e ovaries, the bulk of which weighed less than rams, contained only early developing eggs; maximum egg diameter measured was 0.25 The most enlarged pair of ovaries (131 s) obtained from the largest female fish led (length 108.1 cm., weight 58 lbs.) con- d eggs which measured less than 0.13 mm. in eter. The testes were also immature.

though large fish (longer than 90 cm.) were well represented in the sample, field observa- s of the gonad condition of longline-caught fish supplementary evidence that North Pacific were either sexually immature juveniles, or adult fish with early developing gonads. Table 6 lists the observations, based strictly on gross inspection, recorded by various members of the POFI staff. Presumably, the gonads of these large fish were sufficiently enlarged so that sex could be determined with some assurance. While the observations recorded as "spent," "spawned-out," and "recovering" might be questioned, there is little doubt that the "immature" fish, corresponding to our early developing category, were correctly designated. The observation dated January 28, 1955 (table 6), for a male albacore of 93.3 cm., is not necessarily indicative of advanced maturity. Male albacore taken in tropical and subtropical waters almost invariably contain some milt in the testes regardless of the size of the gonads. Brock (1943) found that milt could be squeezed from the testes of albacore captured off the coast of Oregon, but the females from this region were judged to be immature.

Our observations indicate that albacore in the central and eastern North Pacific are either sexually immature fish, or are adults which do not show signs of near-spawning. Partlo (1955)

TABLE 6.—*Field observations on sex and maturity of large albacore (over 90 cm.) taken on longline during POFI cruises to the North Pacific* [1]

Date of capture	Position of capture		Fork length, cm.	Sex	Description of gonad condition
	Latitude	Longitude			
Jan. 22, 1954	26°28′ N.	159°39′ W.	107.5	M	Immature.
Jan. 27	33°58′ N.	159°44′ W.	118.3	M	Do.
Do	33°58′ N.	159°44′ W.	112.7	M	Do.
Do	33°58′ N.	159°44′ W.	111.6	M	Do.
Do	33°58′ N.	159°44′ W.	110.7	M	Do.
Do	33°58′ N.	159°44′ W.	109.7	M	Do.
Do	33°58′ N.	159°44′ W.	107.4	M	Do.
Do	33°58′ N.	159°44′ W.	107.4	M	Do.
Do	33°58′ N.	159°44′ W.	106.1	M	Recovering.
Do	33°58′ N.	159°44′ W.	106.1	M	Immature.
Do	33°58′ N.	159°44′ W.	105.7	F	Spawned-out.
Do	33°58′ N.	159°44′ W.	104.5	F	Spent.
Do	33°58′ N.	159°44′ W.	102.5	M	Immature.
Do	33°58′ N.	159°44′ W.	99.4	M	Do.
Jan. 28	35°27′ N.	159°38′ W.	109.1	M	Do.
Oct. 24	38°40′ N.	175°27′ W.	107.6	F	Spent.
Dec. 9	34°23′ N.	159°48′ W.	113.6	M	Immature.
Do	34°23′ N.	159°48′ W.	110.7	M	Do.
Dec. 12	36°14′ N.	159°55′ W.	115.9	M	Do.
Do	36°14′ N.	159°55′ W.	96.8	F	Do.
Dec. 14	35°35′ N.	158°21′ W.	116.1	M	Do.
Do	35°35′ N.	158°21′ W.	114.8	M	Do.
Do	35°35′ N.	158°21′ W.	110.4	M	Do.
Jan. 17, 1955	33°50′ N.	179°44′ W.	104.5	M	Do.
Jan. 18	35°48′ N.	179°49′ W.	116.8	M	Do.
Do	35°48′ N.	179°49′ W.	113.0	M	Do.
Jan. 20	31°25′ N.	178°08′ W.	110.0	M	Do.
Jan. 28	30°42′ N.	175°01′ W.	93.3	M	Some milt in testes.[2]
Do	30°42′ N.	175°01′ W.	90.6	M	No milt in testes.

[1] Includes only those observations in which both sex and gonad condition were recorded.

[2] The presence of milt in the testes does not necessarily indicate advanced maturity, as male albacore taken in tropical and subtropical waters almost invariably contain some milt in testes regardless of the degree of sexual maturity.

who examined histologically a series of male and female gonads, concluded that the British Columbia fishery is dependent on immature fish.

Brock (1943) recorded a range in egg diamet
0.01 to 0.1 mm. in Oregon albacore. He rep
that "fish with ripening ova are not prese
the Oregon fishery and have never been rec
from the California fishery." Kishinouye (
found no fish with maturing reproductive elem
in Japanese waters. According to Suda (1
albacore captured west of Midway Islands, r
of the Subtropical Convergence, are all extre
immature, with gonad weights below 50 gram
both males and females. Thus, the alb
resource which furnishes the basis for the s
live-bait fishery in Japanese coastal waters
the Japanese winter longline fishery in mido
as well as the American west coast fishery i
summer, is composed either of sexually imm
fish, or of adult fish which show no signs of g
development beyond the early developing s
The implications are, therefore, that albaco
not spawn in the temperate waters of the N
Pacific.

HAWAIIAN ISLANDS

Because of the great predominance of mal
the landings of albacore in the Hawaiian Isl
(fig. 7), coupled with the small numbers ta
we had hoped initially to utilize both male
female gonads in this study. We found, howe
that the presence or absence of milt is n

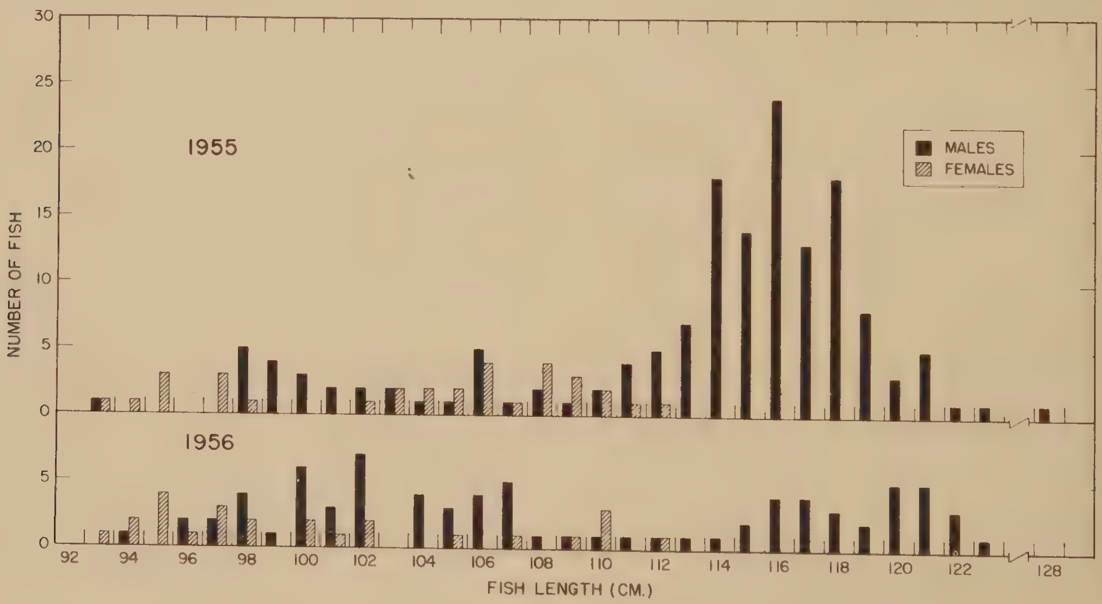


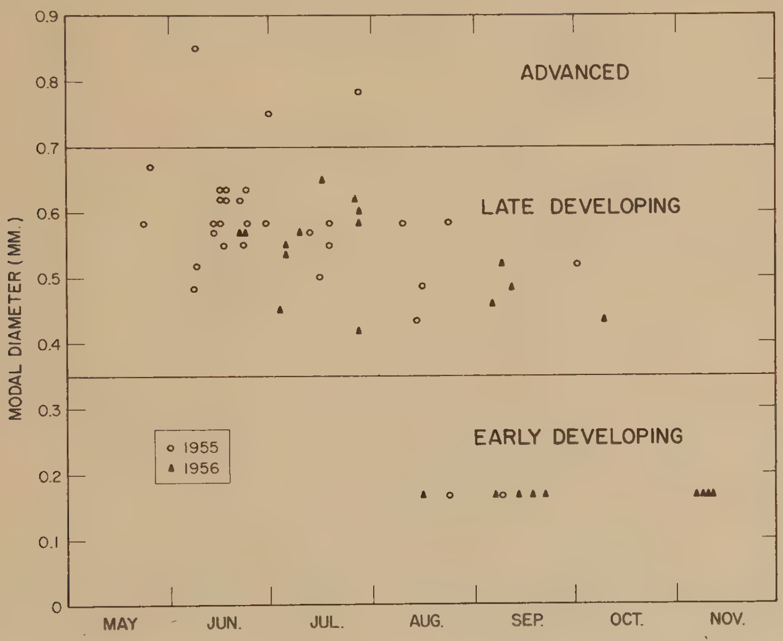
FIGURE 7.—Size and sex distribution of albacore sampled from landings in the Hawaiian Islands, (a) 1955 (b) 19

itive measure of maturity, since regardless of size, the testes of albacore in Hawaii invari- contain some milt. It was decided, there- that only the ovaries would be used for the y of sexual maturity of the Hawaiian and ral equatorial Pacific albacore.

xamination of the ovaries from 56 fish revealed ing degrees of maturity from early developing lvanced. Eleven fish ranging in weight from to 59 pounds possessed early developing ies; 42 fish, ranging from 33 to 62 pounds, had developing ovaries; and 3 fish, of 41, 47, and ounds, contained advanced ovaries. The uency distributions of egg diameters for the te developing and 3 advanced ovaries, and of the early developing ovaries are presented ble 7. No measurements were made on the inder of the early developing ovaries with the ption of noting their maximum egg diameters; exceeded 0.23 mm. The data (table 7) are nged progressively from the early developing he most advanced ovaries as determined by position of the last mode. The modal diam- s indicated here were selected by eye after the had been smoothed twice by a moving age of three. Most of the ovaries showed stinct second mode which is also indicated.

he modal diameters of the most advanced eggs in each of the 56 ovaries of Hawaiian fish are shown in figure 8 by date of landing. The modal diameters of the 11 early developing ovaries are plotted arbitrarily at 0.167 mm. (10 micrometer units) although the true mode was considerably below this value; only eggs larger than 10 micrometer units were measured.

Of the 36 ovaries sampled in May, June, and July, 3 were advanced and 33 were in the late developing stage; none was in the early developing stage. In August and September, however, of 14 examined, only 7 were in the late developing stage; the remainder were early developing. In October and November, of 6 examined, only 2 were in the late developing stage and 4 were early developing. The above may be an indication that some spawning took place during the summer months. Although the 3 advanced ovaries were not fully ripe, the appearance of the eggs suggested that spawning was not far distant. Clark (1929) examined 21 albacore from Hawaiian waters during the summer of 1929 and reported that all of these fish were "practically mature and ready to spawn." On the other hand, it is possible that albacore have a protracted spawning season, and that the apparent summer spawning season in Hawaii merely reflects seasonality in their occurrence in these waters (table 1).



URE 8.—Modal diameter of the most advanced group of eggs shown by date of landing for each of the 56 albacore from Hawaiian waters.

TABLE 7.—*Frequencies of egg diameters, in micrometer units (upper figu*

[Asterisks mark modal diameters]

Ovary number	10 .167	11 .184	12 .200	13 .217	14 .234	15 .250	16 .267	17 .284	18 .301	19 .317	20 .334	21 .351	22 .367	23 .384	24 .401	25 .418	26 .434	27 .451	28 .468	29 .484	30 .501	31 .518
200	175	119	119	65	38	23	5	4	2	----	----	----	----	----	----	----	----	----	----	----	----	----
184	142	100	88	65	76	46	21	9	3	----	----	----	----	----	----	----	----	----	----	----	----	----
318	57	37	26	27	14	15	8	7	8	1	----	----	----	----	----	----	----	----	----	----	----	----
290	60	36	29	15	15	14	8	5	4	8	3	1	1	1	----	----	----	----	----	----	----	----
276	125	79	65	52	52	35	24	16	10	10	12	2	2	9	12	*12	5	6	7	6	3	2
353	32	15	15	9	4	10	12	7	8	7	3	3	5	5	8	10	*16	11	9	3	4	4
179	114	61	46	38	39	31	22	20	19	17	6	6	12	8	12	11	*12	16	10	8	6	5
264	105	66	38	39	40	39	24	24	18	29	12	10	13	13	6	8	10	*16	9	7	8	7
300	92	53	59	37	32	23	17	12	16	9	8	9	11	16	18	16	19	19	*24	19	18	13
32	64	31	25	35	25	30	18	21	16	14	12	11	5	19	11	15	16	21	21	*24	17	23
181	75	48	43	50	45	32	23	24	20	22	9	8	11	12	*22	18	14	7	13	*16	14	11
314	62	38	28	23	23	15	10	18	*22	14	12	13	12	25	14	16	15	23	34	*24	29	29
156	75	59	37	43	48	30	19	20	21	17	6	12	6	8	8	11	15	20	15	12	*24	12
41	58	36	31	22	12	14	24	*23	11	16	15	14	14	10	8	10	23	26	24	28	24	*36
305	85	48	37	33	33	22	11	13	18	12	8	20	*12	18	9	10	3	5	18	14	16	*24
209	43	24	18	15	15	11	19	19	8	12	14	15	9	8	6	17	18	30	31	30	34	*50
256	66	35	31	31	27	20	20	12	17	21	16	10	14	13	*13	20	9	13	15	14	16	30
257	57	31	33	38	39	22	18	20	32	16	15	9	10	16	11	8	7	7	11	12	7	11
88	46	41	30	25	18	18	17	13	11	14	16	19	*13	24	*10	17	11	9	12	9	7	12
116	74	59	42	36	28	38	17	15	16	13	15	10	4	15	13	11	10	4	8	9	6	16
159	71	45	35	30	31	36	11	25	22	24	18	13	17	20	11	10	5	8	14	7	9	9
251	72	42	27	28	27	24	19	18	23	23	14	13	13	*20	19	15	9	12	12	7	8	8
246	62	38	25	24	21	26	12	16	24	22	11	7	10	20	*23	20	10	13	16	11	8	11
259	62	30	26	21	12	20	19	19	30	17	10	11	14	14	14	*23	13	9	16	11	13	17
153	215	151	167	154	161	137	98	88	88	93	82	50	60	69	78	*87	56	67	38	41	25	34
74	259	137	124	117	107	115	82	72	75	69	51	48	54	*56	45	59	40	39	47	29	32	16
185	77	44	37	30	27	33	22	15	16	15	10	7	11	13	10	14	8	16	8	11	16	10
158	35	24	22	23	25	26	18	22	23	19	12	19	16	22	*17	24	9	11	6	4	14	11
275	87	43	39	30	36	29	14	17	16	15	13	9	13	12	*22	15	17	13	10	1	10	4
130	86	54	40	35	30	21	21	17	16	10	12	11	11	8	*13	14	8	10	7	8	7	5
79	76	55	42	36	36	29	22	12	17	21	12	9	9	14	*14	12	8	8	8	7	9	8
75	87	57	46	37	29	26	21	18	22	13	8	9	13	*14	9	11	9	8	7	5	2	8
80	105	51	34	38	39	40	27	29	27	17	13	13	15	14	*22	15	15	8	8	8	10	4
122	53	33	22	21	33	19	15	19	19	18	15	10	14	19	*21	22	11	16	10	7	7	4
174	61	37	23	26	22	40	20	17	19	23	17	13	19	9	15	*22	9	21	11	10	10	4
15	81	30	32	27	18	36	15	15	30	13	21	10	12	16	13	*22	13	9	17	6	6	1
277	102	54	40	40	34	29	15	17	15	15	12	13	6	12	10	*14	6	9	15	7	10	7
274	82	44	36	29	23	23	18	17	16	14	12	6	6	9	8	14	*7	8	13	8	9	7
110	61	30	36	18	27	40	14	23	13	17	21	16	14	11	15	*21	14	8	16	9	9	4
91	49	28	32	25	22	31	20	22	23	18	16	14	15	18	20	*15	6	17	14	13	15	5
82	87	37	34	35	27	29	21	18	23	18	18	14	16	12	10	*17	14	13	11	7	7	3
123	67	35	31	31	24	21	19	14	18	17	12	9	12	18	9	19	*13	14	22	7	3	1
84	72	40	33	25	22	24	17	15	25	13	12	9	13	17	20	*20	16	13	20	11	9	11
90	44	32	25	32	27	27	25	14	19	11	17	8	10	21	*16	21	8	16	19	12	12	4
269	32	22	24	25	11	17	21	21	12	11	16	7	12	19	15	*33	24	15	13	13	1	6
18	61	41	28	29	31	27	11	24	20	11	12	9	5	13	15	*16	12	16	13	4	10	0
145	189	94	83	85	74	93	52	61	66	46	44	36	38	47	40	49	42	*53	47	24	13	4
165	86	63	54	41	44	37	31	28	29	26	15	4	12	13	13	*15	10	12	12	8	6	6
42	104	58	28	29	16	23	10	8	18	15	17	12	10	9	10	9	8	10	12	4	7	4

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[1] No measurements were made on 7 of the 11 early developing ovaries with the exception of noting the maximum egg diameters; none exceeded 0.23

CENTRAL EQUATORIAL PACIFIC

While the vast region of the tropical Pacific is here treated as a single unit because of the small amount of data available, it is realized that a more detailed study of smaller units of area would be desirable.

The albacore caught in the equatorial Pacific (fig. 9) were intermediate in size between those from the North Pacific and those from Hawaii. If only the female fish are considered, however, their sizes were not much smaller than the female fish sampled from Hawaiian waters. One notable difference was in the sex ratio, which in this region was nearly 1:1, while in Hawaiian waters the males predominated (fig. 7).

Ovaries from 66 fish were examined. Of this total, 54 were in the early developing and 12 were in the late developing stage (table 8). figure 10 the maximum egg diameter of eac the 66 ovaries is shown by date of capture of fish. Maximum egg diameter was used, bec no other measurements were made on mos the early developing ovaries. Most of the s ples were collected during February and Nov ber 1952, in February and May 1953, Septen 1956, and January and February 1957. S late developing ovaries were found during a these periods with the exception of February 1 The areas from which late developing ov were obtained are also indicated in figure 1. T appear to be randomly scattered. It is evi that no conclusions can be drawn from the am of data available regarding the spawning and locality.

mm. (lower figure), for ovaries from the Hawaiian Islands [1]

[Asterisks mark modal diameters]

34 .568	35 .584	36 .601	37 .618	38 .635	39 .651	40 .668	41 .685	42 .701	43 .718	44 .735	45 .752	46 .768	47 .785	48 .802	49 .818	50 .835	51 .852	52 .868	53 .885	54 .902	55 .918	56 .935	57 .952	58 .969	59 .985	Sum
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	200
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2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	200
4	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	531
1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
0	2	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
8	13	7	8	2	1	0	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
1	2	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
8	5	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
6	1	1	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
6	5	4	3	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
15	12	4	4	4	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
12	12	9	4	1	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
12	15	4	0	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
26	19	11	10	3	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
28	25	16	9	10	6	2	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
17	19	5	4	1	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
13	16	7	6	6	3	1	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
*16	16	7	10	11	6	4	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
*25	25	18	8	5	2	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
*17	23	20	10	8	3	2	1	1	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
*69	67	53	21	9	4	0	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2, 391
*27	27	18	20	19	10	6	2	3	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1, 847
*17	16	12	10	10	4	4	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
*27	33	17	12	8	5	2	0	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
9	*19	12	14	6	5	4	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
13	*21	13	17	9	7	3	1	1	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
10	*10	15	11	4	4	4	1	1	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
15	*21	12	9	4	3	2	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
15	*14	10	6	9	7	2	2	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	634
20	*25	21	21	17	8	4	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
13	*24	14	15	8	6	6	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
13	*24	16	14	6	4	2	3	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
3	10	*7	8	8	5	6	3	1	3	0	1	0	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
8	15	21	*25	21	13	8	6	4	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
9	11	10	*25	7	11	11	7	7	6	0	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
9	9	8	*19	11	8	13	5	6	1	0	0	0	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
8	9	6	*15	14	13	3	1	3	1	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
10	15	17	17	*26	14	14	6	4	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
2	1	9	7	*12	6	8	8	9	10	4	1	3	1	1	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
8	11	12	14	*22	9	21	11	7	3	1	1	0	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
10	10	20	16	27	*31	19	17	10	5	1	2	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
2	2	4	11	18	15	*21	15	11	15	7	10	0	3	1	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	550
4	7	3	11	11	13	15	11	16	23	24	*30	24	28	22	11	10	4	5	2	3	1	1	0	1	-----	1, 568
2	0	1	0	1	1	1	2	6	5	5	5	7	*9	6	5	5	5	6	4	3	2	1	2	-----	-----	656
1	2	1	0	0	0	1	0	0	1	1	1	1	11	6	6	16	*9	10	15	2	12	7	5	0	2	550

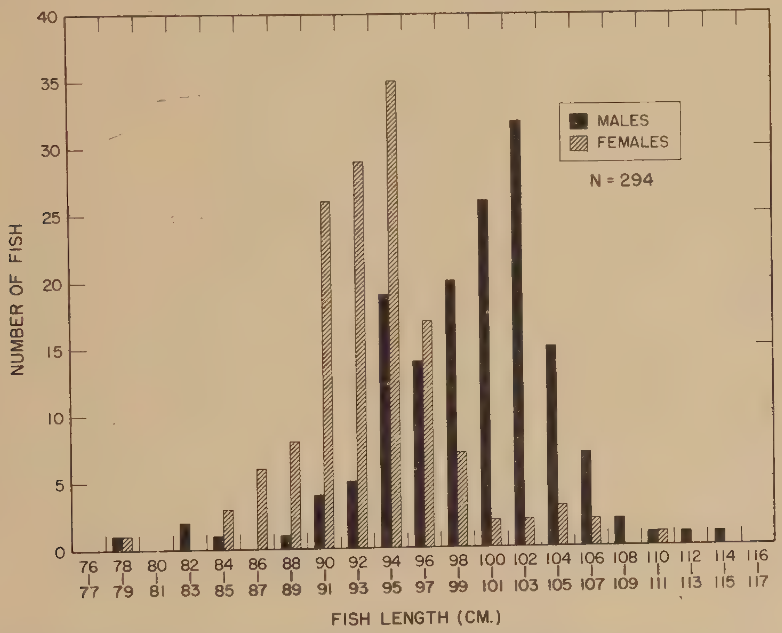

FIGURE 9.—Size distribution, by sex, of central equatorial Pacific albacore captured during the years 1952 to 1957, and for which sex and size data were recorded.

TABLE 8.—*Frequencies of egg diameters, in micrometer units (upper figure) and mm. (lower figure), for ovaries from the central equatorial Pacific Ocean* [1]

[Asterisks mark modal diameters]

Ovary number	10 .167	11 .184	12 .200	13 .217	14 .234	15 .250	16 .267	17 .284	18 .301	19 .317	20 .334	21 .351	22 .367	23 .384	24 .401	25 .418	26 .434	27 .451	28 .468	29 .484	30 .501	31 .518	32 .534	33 .551	34 .568	35 .584	36 .601	37 .618	38 .635	39 .651	40 .668	41 .685	42 .701	Sum
C-16	126	82	72	53	36	37	27	31	28	17	13	13	10	2	2	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	550
C-49	39	23	16	20	18	7	18	13	5	5	*11	4	3	5	3	2	3	1	0	3	1	----	----	----	----	----	----	----	----	----	----	----	----	200
C-48	26	13	11	9	8	17	13	13	3	3	15	*10	10	7	8	8	10	4	5	4	3	----	----	----	----	----	----	----	----	----	----	----	----	200
C-3	57	42	35	22	28	33	30	14	18	16	14	18	19	20	22	*28	27	18	15	14	12	12	9	10	5	6	1	3	2	----	----	----	----	550
C-42	94	48	41	33	27	30	22	21	17	20	20	23	24	19	18	*24	27	12	15	5	4	3	0	0	2	0	1	----	----	----	----	----	----	550
C-20	67	39	38	22	23	19	16	*30	24	20	17	16	20	22	12	32	*21	27	27	10	18	14	7	6	2	1	----	----	----	----	----	----	----	550
C-31	126	77	57	31	19	20	13	8	10	3	6	12	9	12	12	13	20	*22	22	12	10	13	12	6	0	2	3	----	----	----	----	----	----	550
C-10	119	75	58	54	36	31	11	22	16	11	12	5	14	15	8	9	10	11	*16	7	2	3	2	2	1	----	----	----	----	----	----	----	----	550
C-61	61	35	30	29	32	30	25	23	24	15	22	20	19	19	13	18	23	22	*23	26	20	10	8	2	1	----	----	----	----	----	----	----	----	550
C-37	72	44	44	36	17	23	23	24	19	17	12	9	15	15	7	16	21	21	*20	20	16	8	9	9	12	8	3	3	3	3	0	0	1	550
C-1	58	28	25	19	15	14	14	15	14	20	20	16	16	17	22	15	20	22	16	18	26	*23	22	24	18	15	9	5	3	0	1	----	----	550
C-13	117	86	81	49	34	21	21	20	14	12	8	8	4	2	0	3	7	5	9	6	9	*13	3	4	5	5	1	1	1	0	0	0	1	550
C-2	96	56	36	25	23	20	11	20	12	10	15	11	10	11	9	12	17	16	19	11	16	*19	15	13	11	9	8	6	7	2	1	2	1	550

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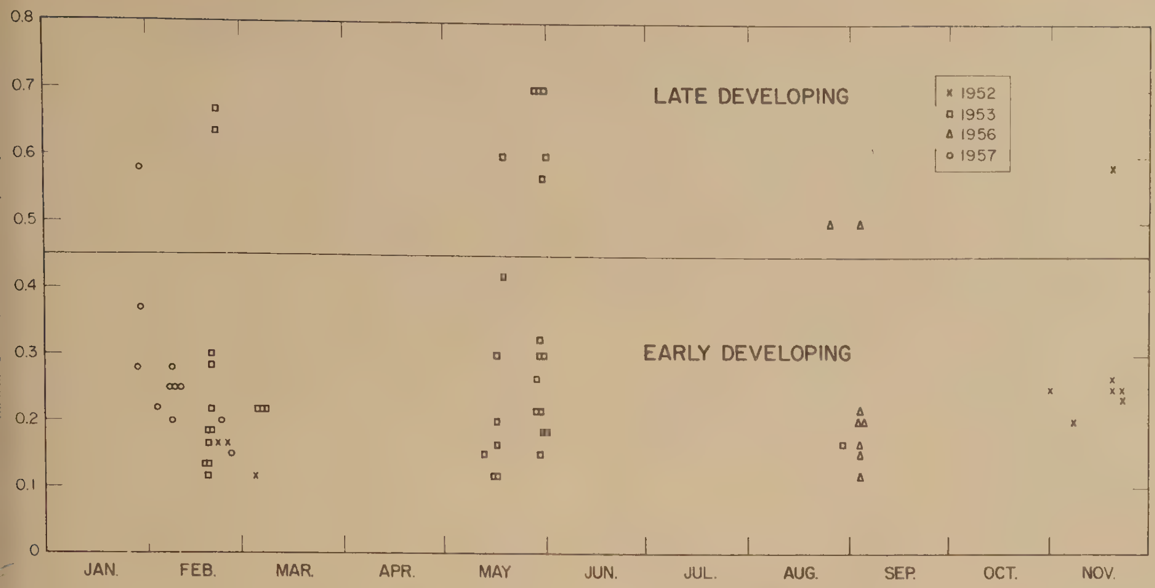
[1] Eggs from only one early developing ovary (albacore No. C-16) were measured.



RE 10.—Maximum egg diameter for each of the 66 central equatorial Pacific albacore by date of capture. (Since nly the maximum egg diameter was recorded for most of the early developing ovaries, this measurement rather han the modal diameter is used.)

EVIDENCE OF SPAWNING

ie spawned-out or spent stage is recognized ie presence of remnants of ripe eggs (residual in the process of resorption) in the lumen of ovary (Schaefer and Orange, 1956; Yuen and , 1957). A fresh, unpreserved spent ovary is rally hollow and flaccid. In preserved speci- s, however, it may resemble any of the other es of maturity, even the early developing y, depending upon how recently spawning occurred. Egg remnants were actually found varies in all stages of maturity from early loping through advanced.

this study we classified the ovaries into lopmental stages without regard to the pres- or absence of egg remnants. In figure 11 maximum egg diameter for each of the Hawai- and central equatorial Pacific albacore is shown ish size, and the ovaries which contained egg nants are indicated. No distinction was made ie quantity of remnants in the ovaries, nor of stage of resorption. While the absence of remants may not be accepted as proof that fish has never spawned, their presence con- ites good evidence that spawning has oc- ed (June 1953; Yuen 1955; Schaefer and nge, 1956; Yuen and June, 1957). Of a total of Hawaii samples, 47 contained egg remnants, cating that these fish had spawned. Similarly 6 central equatorial Pacific ovaries examined,

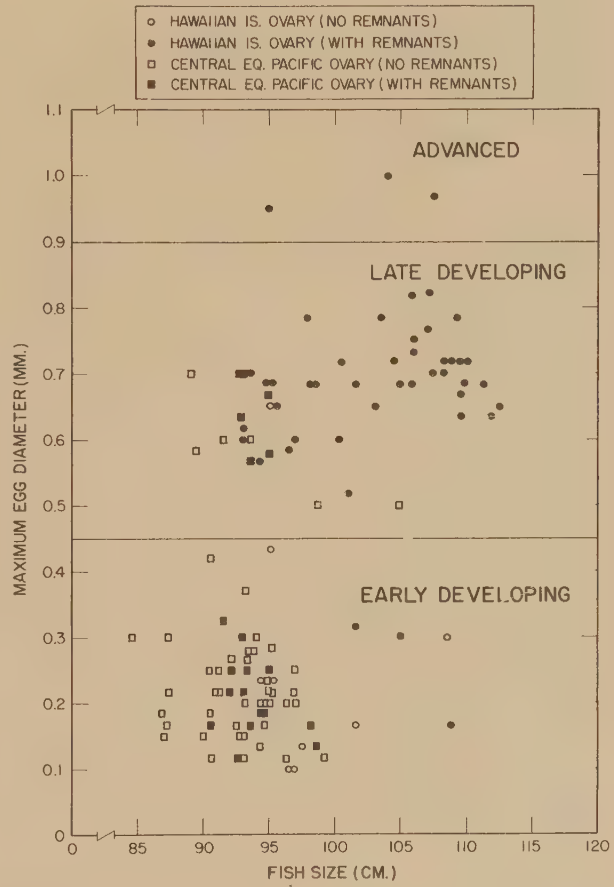


FIGURE 11. Relation between fish size and maximum egg diameter. Ovaries with egg remnants are indicated.

20 contained egg remnants. None were found in the North Pacific ovaries, thus giving added weight to the conclusion that spawning does not occur in the North Pacific.

MINIMUM SIZE OF SPAWNING FISH

Ueyanagi (1955) has inferred from his studies that the albacore attains sexual maturity and may spawn at about 90 centimeters in length. Our observations are in agreement with this.

The 12 central equatorial Pacific ovaries in the late developing stage were obtained from fish ranging in length from 89.1 cm. to 104.8 cm. (weight, 33 to 54 lbs.); the 45 late developing and advanced ovaries from the Hawaiian area were taken from fish larger than 93.1 cm. (33 lbs.). Additional evidence regarding the minimum size at spawning can be found in figure 11. Although egg remnants were present in ovaries at all stages of maturity, none were found in fish less than 90 cm. in length. Therefore, our data suggest that the albacore attains sexual maturity at a size of about 90 cm. (33 lbs.), which coincides with Ueyanagi's findings.

FREQUENCY OF SPAWNING

The frequency distributions of egg diameters (figs. 5 and 6, tables 7 and 8) show clearly two or more modes which, depending on the growth rate of the egg, may represent eggs that will be spawned in a single season or in succeeding seasons. As the data do not permit determination of the growth rate of eggs, reference is again made to figure 11. The fact that the three advanced ovaries as well as most of the late developing ovaries contained egg remnants strongly indicates that the albacore undergoes multiple spawning. The lack of remnants in large, sexually inactive adults taken during late winter in the North Pacific suggests that remnants are not carried over from one year to the next, though in the absence of any knowledge regarding the rate of resorption of the unspawned eggs, no definite conclusions can be drawn. The presence of egg remnants together with a group of eggs approaching ripeness suggest, however, that albacore may spawn at least twice during a single spawning season.

FECUNDITY

Fecundity calculations were based o
assumption that all of the eggs comprisin
most advanced group within an ovary
released in a single spawning. Eight Hav
fish of varying sizes were selected for this s
From each pair of ovaries, a random sampl
obtained; this was weighed to the nearest
gram. All of the eggs comprising the
advanced group within the sample were
counted. The total number of such eggs i
pair of ovaries was estimated by multiplyi
number in the sample by the ratio of
weight to sample-weight. The results are
in table 9. The data are arranged in the or
increasing fish size from 36 to 62 pound
addition, two calculations made by Uey
(1955) are included.

TABLE 9.—*Estimations of the number of eggs in th advanced group in the ovaries*

Albacore No.	Body wt. (lbs.)	Ovary wt. (gms.)	Sample wt. (gms.)	Number of mature eggs in sample
158	36	183	0.1215	579
75	39	271	.1862	882
275	41	319	.1435	418
42	47	538	.2367	482
74	54	513	.0560	513
84	57	552	.1983	582
145	60	916	.1197	238
153	62	194	.0811	411
A [1]	50	365	.2	----------
B [1]	53	613	.2	----------

[1] From Ueyanagi (1955).

There appears to be a slight tendenc
larger fish to have more eggs per spawning
is not as definite as that found for the yel
(June 1953) and bigeye tuna (Yuen 1955).
estimated total numbers of eggs in the
advanced group were remarkably uniform,
ing between 0.9 and 1.8 million eggs per indi
female. Including Ueyanagi's estimates, the
is from 0.9 to 2.1 million eggs.

OVARY SIZE AS INDEX OF MATU

While the state of maturity of an ovary
determined reliably by means of egg dia
measurements, a more simple and yet obj

d for making rapid field determinations is ble. The size of the ovaries, if directly l to maturity, should provide a reasonable on. Our data show that all of the early ping ovaries from the central equatorial c weighed less than 100 grams, and that eveloping ovaries ranged from 104 to 363 . The early developing ovaries from the iian area, however, ranged in weight from 179 grams, the late developing ovaries from 805 grams, and the three advanced ovaries ed 181, 538, and 916 grams, respectively. while the ovaries from the central equatorial c fall conveniently into two stages of rity according to their weights, there is lerable overlap in the Hawaiian samples. pears, therefore, that ovary size is actually a criterion to follow in assessing the state of rity of an ovary.

cently, the relative ovary weight (ovary nt × 10³/fish weight) has been found to be ly reliable measure of maturity for Hawaiian wfin (June 1953) and central Pacific bigeye (Yuen 1955). This relation was therefore d for the albacore ovaries. In figure 12 the rel- ovary weight of each of the Hawaiian and central equatorial Pacific albacore is plotted against the maximum egg diameter. Here again, the data do not permit the use of modal diameters, for these were not determined for most of the early developing ovaries. The data presented in tables 7 and 8 indicate an acceptable correlation between modal and maximum diameters which justifies the use of the latter. The early developing ovaries, with only one exception, have relative ovary weights of less than 6, while all but three of the late developing ovaries have relative ovary weights greater than 6. Thus, with a reasonable amount of confidence, a relative ovary weight of 6 may be considered as the value which separates the early developing from late developing ovaries.

The late developing ovaries ranged in relative ovary weight from 6 to 30 with a general tendency for the ratio to increase with progressing maturity. The three advanced ovaries, however, failed to conform to any pattern and varied in relative ovary weights from 10 to 34. Despite the large variation exhibited by the three ovaries in the advanced stage, the data in general point to a definite relation between relative ovary weight and the state of gonad development.

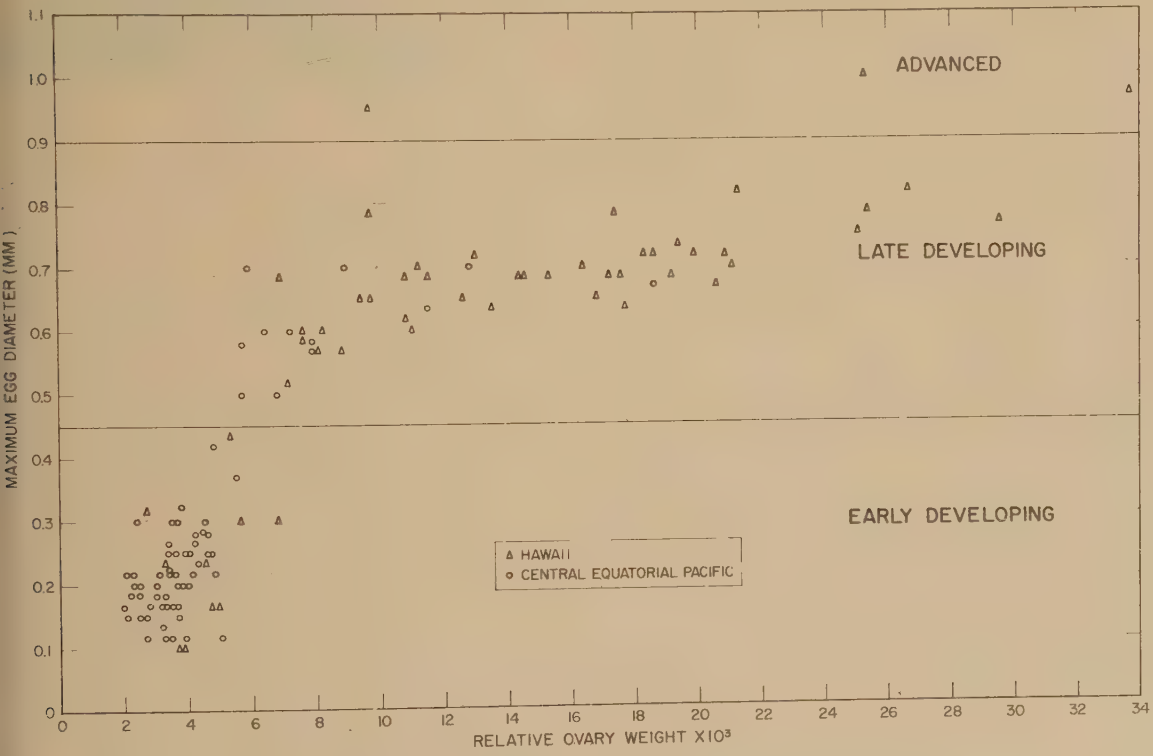


FIGURE 12.—Relation between relative ovary weight and state of maturity.

DISCUSSION

Our samples did not include any ovaries that were fully ripe. Three ovaries were classified as "advanced" on the basis of the appearance of the eggs. Although they were advanced in maturity, and presumably close to spawning, it has not been possible to determine the time required for these ovaries to attain a fully ripe stage. Because these advanced ovaries were collected during the summer months, and since a large percentage of ovaries collected in the fall were in the early developing stage (fig. 8), it was postulated that some spawning occurs during the summer in the vicinity of the Hawaiian Islands.

Fully ripe fish apparently are not available to the fishery. June (1953), working with Hawaiian yellowfin, concluded that this species spawns in Hawaiian waters. He found only one fully ripe ovary among his samples, however, and stated that "fish that are actually spawning either do not take the hook or migrate into deeper water outside the longlining grounds." Similarly, Schaefer and Orange (1956) stated that "apparently, when the yellowfin tuna imminently approach spawning, they become unavailable to the fishery." This behavior was noted earlier by Schaefer (1948) for yellowfin tuna and skipjack off Central America. Brock (1954) also found that fully ripe skipjack are not commonly available to the Hawaiian skipjack fishery. Thus, the possibility that fully ripe tunas are generally unavailable to the fishery may be one reason for the small number of advanced ovaries and the complete absence of ripe ovaries in our collections.

Most of the ovaries examined from the central equatorial Pacific were in the early developing stage, but a few late developing ovaries were present as well as those that contained relics of past spawning. Absence of advanced stages may mean that these fish do not spawn in this region. Unfortunately, not much is known of the maturity of the albacore taken in other regions of the tropical Pacific. Some field observations on the gonads of albacore landed by the Japanese tuna mothership expeditions between April and September of 1951 are available for the western equatorial Pacific between the Equator and 6° N. latitude and between 144° E. and 174° E. longitude (general vicinity of the Caroline and Marshall Islands). Descriptions of these expeditions are given by Shimada (1951), Ego and Otsu (1952), and Van Campen (1952). Of a total
observations made by observers from
during this period, 33 were recorded as imm
6 as spent, and only 2 as mature. Judging
these records, it may be assumed that the ma
of the western Pacific albacore during this
more nearly resembled that of the central
torial Pacific albacore than that of the Ha
fish.

Ishii and Inoue (1956) postulated that the
Sea and adjacent New Caledonia area
spawning areas for the albacore. Their stud
based on only two ovaries which, accordi
their descriptions, corresponded to our
developing and late developing stages. O
basis of these data, it is surmised that the ma
of the fish in this area is much like that
throughout the central and western equa

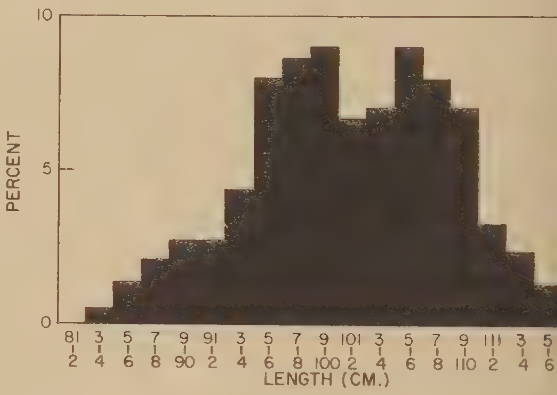


FIGURE 13.—Length composition of Indian Ocean al
(reproduced from Ueyanagi 1955, fig. 2).

Pacific. It is interesting to note that Uey
(1955) reported on two well-advanced o
obtained in February 1953 from the sou
waters of Sunda Islands (Indian Ocean); o
the ovaries he referred to as "ripe" and the
as "nearly ripe".[2] He has hypothesized tha
albacore which occur in the Indian Ocean s
in February, at least, in part. He believes
the area from south of the Sunda Chain to n
west of Australia may be the spawning grou
the Indian Ocean albacore, since the fish
there are generally large. Ueyanagi's siz
quency data of the Indian Ocean albacore (fi

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[2] Ueyanagi very kindly sent us samples taken from these two
The sample he referred to as "nearly ripe" corresponds in maturit
developing ovaries, and the "ripe" to one of the advanced ovarie
present study.

resemble that of the central equatorial albacore (fig. 9).

best indications of albacore spawning are ore available from two widely separated ies, the Hawaiian Islands in the central and Sunda Islands in the Indian Ocean, rmer during the northern summer and the during the southern summer.

s not known whether the albacore appearing ious parts of the Pacific Ocean belong to a intermingling population or whether there iscrete populations in the various areas. (1956) is of the belief that the albacore occur- in the North Pacific Current area are a ng group" and that there is a corresponding ning group" in the North Equatorial Current Furthermore, he postulates that the alba- of the Indian Ocean as well as the tropical Pacific comprise the spawning group of er feeding group located in South Pacific erate waters. If this is indeed the case, it be that the Hawaiian Islands represent a on of the spawning grounds of the northern ation, and that the Sunda Islands, that of uthern population.

r data suggest that albacore attain sexual rity at about 90 centimeters in length ht, 33 lbs.). This signifies that the fish ited during the spring and summer by the nese and the Americans in the temperate s of the North Pacific are largely sexually ture fish (Suda 1955, Brock 1943). The nese winter longline fishery in the North ic, on the other hand, exploits both juvenile adult fish (Suda 1954). The gonads of these fish do not show any development, however. situation is in contrast to that in the Ha- n Islands where the catch is wholly of adult fig. 7). Many of these have gonads showing derable development. In the central equa- l Pacific, the fish are also generally large and are adults with gonad development inter- ate between North Pacific and Hawaiian ds fish. It appears possible that the Ha- n and central equatorial Pacific albacore are ment of the population which, after attaining tain size in temperate waters of the North fic, moves south into tropical and subtropical rs to reproduce.

SUMMARY

1. This study is based on examination of gonads of albacore taken from three general areas: the North Pacific (north of 30° N. latitude, between 180° longitude and the west coast of the United States), the Hawaiian Islands, and the central equatorial Pacific (Equator to 12° S. latitude, between 180° and 150° W. longitude, with scattered samples collected from as far east as 120° W.). Although the three areas are treated separately throughout this report, this does not infer that the fish belonged to separate stocks, or populations.

2. Gonads of both sexes were used in the study of the maturity of North Pacific albacore. Only the ovaries were used for the other two areas and the degree of maturity was determined largely from egg diameter measurements.

3. The several tests made to determine the most efficient sampling procedure indicated that mature eggs were randomly distributed throughout the length of an ovary but there were some differences in the transverse distribution. There were no differences in the distribution between the two ovaries of a pair. The adopted method of sampling was to take a random sample from the mid-section of an ovary.

4. The ovaries were classified in three stages of relative maturity: early developing, late developing, and advanced, on the basis of the most advanced eggs present. The advanced ovaries were not in a fully ripe condition.

5. The North Pacific albacore were either juveniles or sexually dormant adults with early developing gonads.

6. The Hawaiian albacore evinced varying degrees of maturity from early developing to advanced, with the bulk of the ovaries in the late developing stage. Although the samples were somewhat inadequate for a conclusive study, there was indication that spawning may occur during the summer months in the vicinity of the Hawaiian Islands. The data also indicated the possibility of a somewhat protracted spawning season.

7. The ovaries from central equatorial Pacific fish were in the early developing and late developing stages, with the early developing stage predominating.

8. The presence of egg remnants in the ovaries indicated that most of the Hawaiian fish had spawned previously. None of the ovaries from the North Pacific contained egg remnants. Of 66 central equatorial Pacific ovaries, 20 contained egg remnants. Remnants of eggs were present in ovaries in all stages of maturity from early developing through advanced.

9. The minimum size at which albacore attain sexual maturity and participate in spawning appears to be about 90 cm. (weight, 33 lbs.).

10. The size distribution of eggs within an ovary, as well as the frequent occurrences of egg remnants in advanced and late developing ovaries, indicate that albacore may undergo at least two spawnings during a spawning season.

11. Assuming that all of the eggs comprising the most advanced group within an ovary are extruded in a single spawning, the number released per spawning is about 1 to 2 million eggs per individual female albacore.

12. Ovary size is not a reliable criterion to follow in assessing the degree of maturity of an ovary. Relative ovary weight (ovary weight × 10^3/virgule fish weight) is shown to be the more reliable index, particularly for segregating early developing from late developing ovaries.

13. This study shows that albacore caught by POFI vessels north of Hawaii, as well as those taken by the Japanese spring live-bait and winter longline fisheries, and those supporting the American west coast summer fishery are non-spawning fish that are either juveniles or adult fish whose gonads give no signs of incipient or past spawning. Albacore apparently do not spawn in the temperate waters of the North Pacific.

14. It appears possible that the albacore in region of the Hawaiian Islands and in the central equatorial Pacific represent a segment of the population which, after attaining a certain size in temperate waters of the North Pacific, moves south into tropical and subtropical waters to reproduce.

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BY TAMIO OTSU AND RICHARD N. UCHIDA

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FISH AND WILDLIFE SERVICE, Arnie J. Suomela, *Commissioner*

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ABSTRACT

Various hard parts of large (93–128 cm.) albacore, *Germo alalunga* (Bonnaterre), from Hawaiian waters and smaller fish (50–112 cm.) from the central North Pacific were examined for marks that could be used in determining age in this species. A cursory examination of the opercular bones and fin spines revealed no usable marks. A study of scale samples from 100 albacore showed that only one-half of them were readable, and these only with a considerable degree of subjectivity.

Several workers in other areas have reported apparent success in aging albacore by means of the rings on the vertebral centra. Their results could not be duplicated in the present study. In attempts to read the rings in the vertebrae of 212 Hawaiian and 53 central North Pacific albacore, the authors found little agreement between the counts of the different readers or even between successive counts by the same reader. Indications were seen that the rings on the vertebrae are not annuli but rather that they may be growth marks laid down randomly with time. As a clue to relative age, however, they may provide an explanation of the unbalanced sex ratio of large albacore, for they indicate the possibility that among mature fish the males grow faster than the females.

The results of this study, though largely negative, are presented for the information of those engaged at present in similar studies and for others who may work on this problem in the future.

UDY OF AGE DETERMINATION BY HARD PARTS OF ALBACORE FROM CENTRAL NORTH PACIFIC AND HAWAIIAN WATERS

y **Tamio Otsu and Richard N. Uchida,** ***Fishery Research Biologists,*** **U. S. Bureau of Commercial Fisheries**

part of the research program of the Pacific nic Fishery Investigations (POFI), Fish and life Service, a study was initiated to determine ige and growth of albacore, *Germo alalunga* naterre), occurring in the region of the aiian Islands and in the central North Pacific. study and other investigations of the albacore irces of the Pacific are conducted by POFI r Public Laws 329 (80th Congress) and 466 onstall-Kennedy Act, 83d Congress).

veral workers have reported on the age and rth of albacore as determined from surface kings on the vertebral centra. Uno (1936a, b) king with albacore taken by pole-and-line ng in the waters east of Cape Nojima, Japan, e age determinations on 988 fish. Aikawa Kato (1938) reported on age determinations lbacore based on 10 large fish taken near way Island and 5 small fish taken off north- ern Japan. Partlo (1955) studied the age and vth of the eastern Pacific albacore, utilizing vertebrae of 531 fish taken in 1950 from off- e waters adjacent to California, Oregon, shington, and British Columbia. Finally, ieras (1955) reported on age determination of albacore taken off the coast of Galicia in hwestern Spain.

was our hope to extend these findings to ude central North Pacific albacore and the ptionally large fish occurring in the Hawaiian . We assumed that methods employed in r areas to determine the age of albacore ld be successfully employed in this study. efforts in this respect were entirely unsuccess- however, as we were unable to verify or dupli- findings of the other workers. It was our clusion that the markings on albacore hard ts, particularly on the vertebrae, are not true r marks, and therefore, cannot be used in the ng of these fish. The results of our study, ugh largely negative, are presented here for information of those who are presently engaged in similar studies and for others who may work on this problem in the future.

MATERIALS

Scales and vertebrae were routinely collected and certain other skeletal structures such as the operculum and the fin spines were also examined. Between January 1955 and July 1956, vertebrae and scales were collected from 212 albacore taken in Hawaiian waters and 53 from the central North Pacific.

Albacore taken by the Hawaiian longline fishery from an area within 20 miles of the main islands, were generally large, ranging in length from 93 to 128 cm. (weight, 33 to 93 lbs.) (fig. 1). These fish were sampled at the two Honolulu auction markets, the Hawaii Fishing Co., Ltd., and the United Fishing Agency, Ltd., where the landings of the Honolulu-based longline vessels were sold. Albacore were obtained from the central North Pacific on POFI's exploratory fishing cruises,

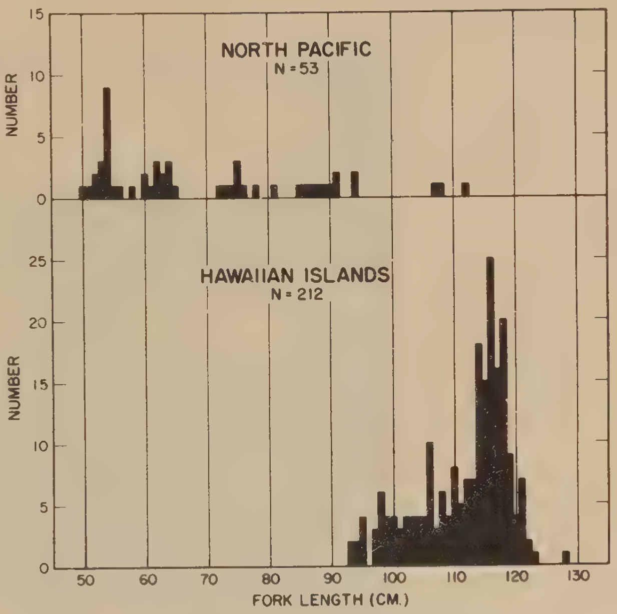

Figure 1.—Length frequency of albacore from which scales and vertebrae were collected.

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which sampled an area between 140° W. and 180° longitude, from 30° to 50° N. latitude. These fish, taken by longline, trolling, and gill nets, were smaller, ranging in length between 50 and 112 cm. (6 to 65 lbs.) (fig. 1).

Scales were collected from the region of the body just below the second dorsal fin. The selection of this region was largely based on recommendations of researchers in California who were similarly engaged in the problem of aging the albacore, and who found scales from that region of the body "most promising" (personal correspondence). The 15th and 16th caudal vertebrae were selected for this study. While past investigators have used the thoracic vertebrae, our choice of the caudal vertebrae was based chiefly on accessibility, or the ease with which they could be acquired in the field or at the auction markets. This difference in the choice of vertebrae appears to be of little significance, since a careful examination of each of the 38 vertebrae of a single albacore revealed no notable differences in the appearance of the concentric markings.

METHODS

The scales were soaked in water overnight, after which the slime and adhering tissue were easily removed. The scales were then either dry-mounted between two glass slides or impressed on 0.030-inch thick cellulose acetate (1″ x 3″)
strips, which were first softened by imme
in 95-percent ethyl alcohol for 5 minutes.

Scale images were projected on a white p
screen with a microprojector. Because of
variable sizes of the scales, the distance betv
the projected image and the microprojector
varied so that approximately equal-sized im
could be produced. This tended to dimi
to some extent the influence of the scale siz
making ring counts.

In processing the vertebrae for study, the
section, cut off at or near the 5th dorsal fi
was boiled in water until the flesh could e
be removed from the bone. After washing,
vertebrae were sun-dried for about 2 days.

The method described by Partlo (1955)
followed in preparing the vertebrae for st
Where the 15th caudal vertebra was cut thro
or damaged during collection, the 16th vert
was used. An electric jig saw was employe
cut each vertebra along a sagittal p
slightly to one side of the median line.
larger of the resulting two parts was sanded d
until the center of the centrum was clearly expo
(fig. 2). Additional cleaning and accentua
of the concentric rings were done by immer
the vertebra in a 1-percent solution of potass
hydroxide for about 48 hours, followed by rin
in fresh water and preservation in 95 perc
ethyl alcohol.

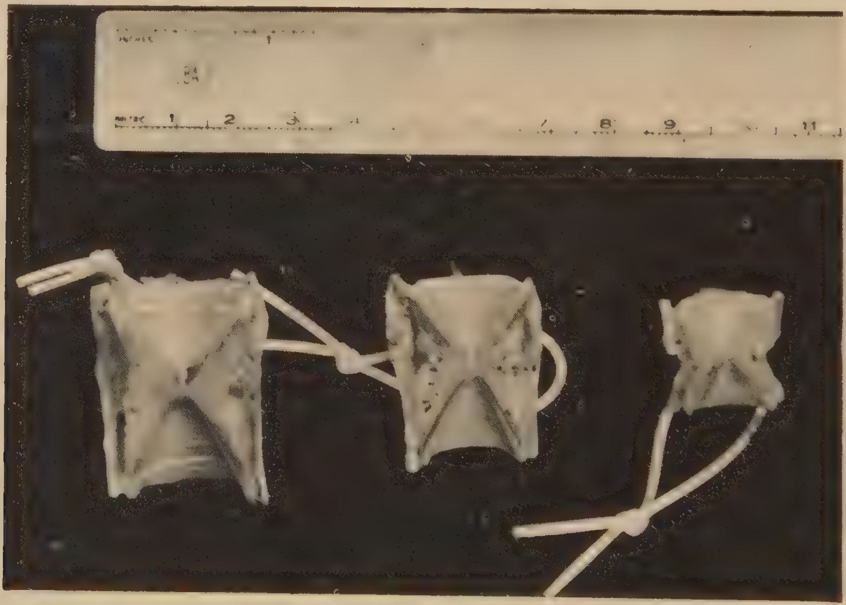


FIGURE 2.—Sectioned and prepared caudal vertebrae taken from albacore 113.9, 100.8, and 75.1 cm. long.

asurements were made from the vertex of one to each ring (ring radius) and also to uter margin of the cone (vertebral radius) the four exposed edges. Ring radii were ıred with a pair of dividers under a disg microscope and read off to the nearest m. on a ruler graduated in 0.5-mm. intervals. anterior and posterior cone measurements treated independently. The two correling ring and vertebral radii measurements ch cone were averaged.

RESULTS

us Skeletal Structures

rsory examination of the operculum, dorsal ectoral fin spines, and the hypural plate prol no evidence that these structures possessed narkings which could be interpreted as "age s." The operculum showed distinct marks on the outer free edge; the central area was iably thickened and devoid of any markings.

s

e albacore scale is cycloid and either oval or ıly rectangular in general outline. The circuli concentric with the margin of the scale. nination revealed that the smaller scales rally exhibited a rather distinct focus and ly defined circuli, but that the larger scales ı fish larger than 90 cm.) were mostly characed by obscure sculpturing and a thickened al area. Furthermore, it was noted in several nces that scales from the same specimen ally in large fish) were of variable size and e. A count was made of the rings on different scales from the same fish following the definiof an annulus as given by Nose and others 5), who state: "The ring appears as a transnt line, near by which the circuli become fine discontinuous . . ." Though the counts on larger scales were necessarily somewhat subve, because of the general opaqueness of the s, there appeared to be some trend in the ber of rings, the smaller scales having a lesser t than the larger. This would seem to indithat the smaller scales had originated more ıtly than the larger ones.

lts of ring counts

ales from 100 fish were examined. Of this l, the scales from 43 fish were considered unreadable, in large part because of opaqueness of the central area. The samples from the remaining 57 fish varied widely in the degree of readability. Despite the obvious difficulties, an attempt was made to count the rings on scales which had the greatest number of annuli for each sample. The ring counts are plotted against fish size in figure 3. There is a tendency for ring counts to increase with increasing fish size, up to 8 rings. The size ranges of fish with 5 or more rings were broad, however, with a great amount of overlapping between successive groups.

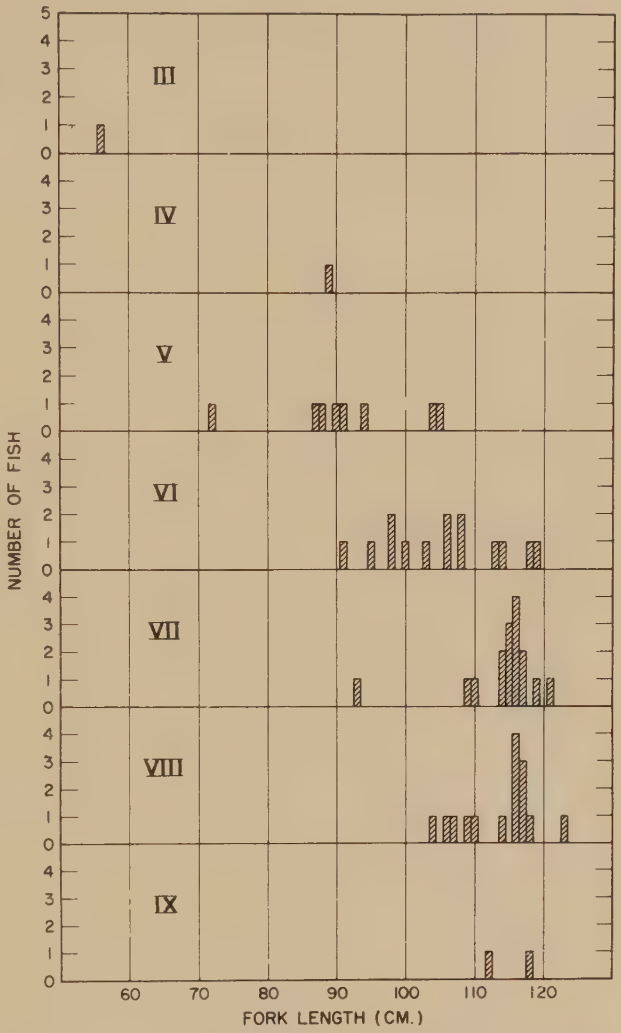


Figure 3.—Age of 57 albacore, determined by scale reading, plotted against fish size. (The Roman numerals represent the number of rings, or "age".)

Moore (1951) in working with Hawaiian yellowfin tuna encountered similar difficulties. He also observed that small specimens of yellowfin, weighing about 5 pounds, had no scales except on the corselet region. He therefore concluded that scales were formed first on the anterior and later on the posterior part of the body. He stated that "if this is the case, any marks laid down in the scales would be of little value until the nature of scale formation and its relation with size and age of fish was known." The nature of scale formation on the albacore has not as yet been determined. Since it was our experience that only about half of the scales examined were considered readable, and these were read with considerable subjectivity, further work with scales was discontinued.

VERTEBRAE

Description

The albacore vertebra is amphicoelous, or concave at both ends of the centrum. A sectioned vertebra shows two cones, the vertices of which meet at or near the middle of the centrum, with their bases forming the margins of the vertebra. On the inner surface of these cones are concentric rings running parallel to the outer margin of the centrum. These rings are described by Partlo (1955) as "narrow translucent zones separated by broad, opaque zones similar to those described by Freidenfelt (1922) for *Lucioperca*. In the albacore the narrow zones were observed not only as translucent bands but also as eruptions or ridges on the centrum surface. The innermost ring differed slightly from the others but was nevertheless clearly marked." We also observed certain rings that appeared as translucent ridges on the surface of the centrum; there were other rings, however, that resembled narrow, translucent bands without any surface eruptions, and still others that were mere suggestions of lines or bands.

Change in the Shape of Vertebrae With Growth of Fish

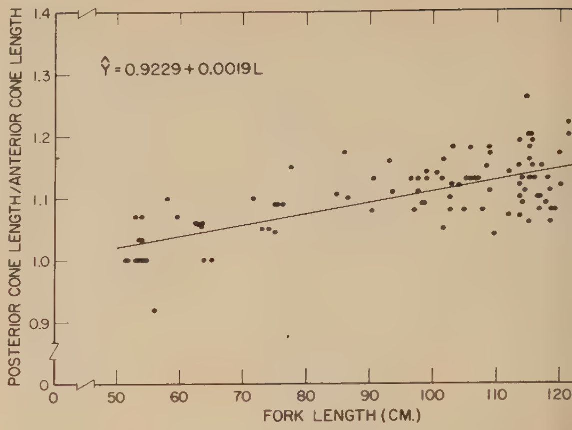


FIGURE 4.—Ratio of the average length of the post and anterior cones plotted against fish size to de strate the disproportionate growth of the two con the amphicoelous vertebrae of albacore.

In the course of examining a wide series of vertebrae, it was noted that while the two cones of an amphicoelous caudal vertebra were nearly the same size in small fish, the posterior cone was larger than the anterior in large fish, indicating that the vertebra changed its shape with growth of the fish. The lengths of the two cones (vertebral radii) were measured and the ratio of the two measurements was plotted against the size of the fish (fig. 4). While the ratio was nearly 1 : 1 in the smallest vertebrae examined (fish around 50 to 60 cm. long), the posterior cone was definitely la than the anterior in the larger vertebrae. changing proportion is described by the rectili regression:

$$\hat{Y}=0.9229+0.0019\ L$$

where $\hat{Y}$ is the ratio of the two cones and L is fork length in centimeters. Although the cones of a caudal vertebra grow disproportiona each cone in itself exhibits a linear growth growth of the fish. Thus, in working with ca vertebrae from a wide size range of fish, important that any measurements of ring or v bral radii, for the purpose of estimating the gro increments of the fish, should be confined to ei the anterior or the posterior cones and no averages of the two. By working with one c growth calculations can be based on the si linear relation between size of the vertebrae size of fish.

Criterion for an annulus

Because of the great variability in the app ance of the rings, it was extremely difficul formulate a satisfactory criterion for an annu In the beginning, we followed the definitio Partlo (1955), who considered as annuli t rings which appeared as ridges on the cent surface. However, as will be discussed, original criterion was later expanded to inc rings which appeared as translucent bands no surface eruptions.

ts of ring counts

ter deciding upon the criterion to be followed, nade a series of independent ring counts and radii measurements. A total of 9 series of ts and measurements resulted in agreements een any 2 series of as low as 8 percent and gh as 45 percent. There was poor agreement only between counts of the two readers but between counts made by the same person. e 1 shows the best agreement attained be- en readers (44.8 percent) and between sets of ings made by the same reader (38.9 percent reader *A* and 43.9 percent for reader *B*). le most of the disagreement was by 1 ring to 50 percent), discrepancies of as many as ngs occurred in many of the comparisons. sistency was often not achieved even between ts of the anterior and posterior cones of the e vertebra.

E 1.—*Best agreement in ring counts between two readers and between any two series of the same reader*

eaders are designated as *A* and *B*; the numerals denote separate read- for example, A_2 represents the second reading made by reader *A*.]

ngs compared	Percentage agreement	Percentage disagreement by:			
		1 ring	2 rings	.3 rings	4 rings
B_3	44.8	38.8	11.9	3.7	0.7
A_3	38.9	50.5	9.8	0.8	0.0
B_4	43.9	47.0	8.3	0.8	0.0

was observed that much of the inconsistency ne counts could be attributed to the difficulty istinguishing rings near the vertex of the cone also at its margin. This does not mean, how- , that the rings on the central portion of the es were clear and easily distinguishable, be- se here also there were many inconsistencies.

ples from small fish

ge determination by means of hard parts fre- ntly becomes more difficult and often breaks n completely in older fish. Therefore, at- pts were made to age fish less than 90 cen- eters in length in order to determine whether not the use of vertebrae from larger, older fish the cause of the poor results. In one trial sisting of two series of counts, the agreement 56 percent for fish less than 90 centimeters ompared with 30 percent for larger fish. The ner agreement with smaller fish is, of course, be expected because of the fewer rings. Further trials with samples of small fish disclosed that the counts were still far too variable to be acceptable as indicators of age.

The vertebrae were examined under natural and incandescent light and also under polarized and various colored lights with no noticeable improvement in the appearance of the rings. Various types of stains were also tried, but here again the results were disappointing from the standpoint of improving the readability of the rings. Thus, we found that we could not satisfactorily duplicate ring counts and therefore could not meet the first prerequisite to the use of vertebrae for aging albacore. Our findings are in contrast to Partlo's, who reported that "counts of rings were reproducible with high consistency."

Determination of time of ring formation

In order to validate the vertebral method for aging albacore, it is necessary that some direct evidence be obtained to show that the rings on the centra are true year marks, which are laid down annually. It appears reasonable to assume that if these rings are laid down regularly once each year, rather than randomly, a study of the margins of vertebrae collected periodically throughout a year should indicate the approximate period of ring formation. The width of the margin from the last ring to the edge of the centrum (the increment of the last ring) should be at a maximum immediately before, and at a minimum just at or after the formation of the last ring. A description of such a method of analysis for the determination of time of ring formation on tuna scales is given by Nose and others (1955).

An attempt was made to obtain some indication of the time of ring formation, despite the fact that any such study would probably be futile unless the rings or annuli could first be read with assurance. Measurements were made from the mid-point of the centrum to the margin of the vertebra (vertebral radius T) and to the last ring (ring radius R_n). Although the last ring was carefully selected in each instance, there was a possibility of error because rings on the margins were often indistinct. The difference between the vertebral and last-ring radii was considered the increment. Figure 5 shows a plot of the relative increment (absolute increment/vertebral radius) plotted against the month of capture of the fish. The data show no indication of regularity in time

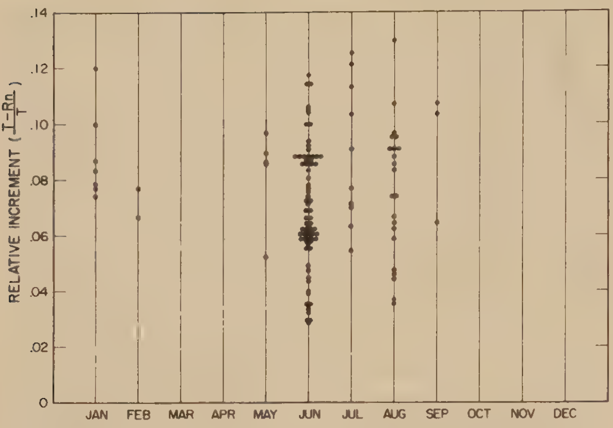


FIGURE 5.—Relative increment of the last ring plotted by month of capture of the fish.

of ring formation. Similarly, a plot of the absolute increment against time of capture resulted in a random scatter of points.

DISCUSSION

Previous investigators working on albacore age and growth have reported the presence of definite rings on the inner surface of the centrum of albacore vertebrae which, they believed, could be used as age indicators. They concluded that each of these rings represented an annulus and, therefore, assigned fish to specific age groups after making counts of these rings. Aikawa and Kato (1938) found that Uno's mean lengths (Uno 1936a, b) for age groups IV, V, and VI fell within the length range that they had established for these same age groups. Partlo (1955), on the other hand, found his ring radii values to be at variance with those observed by Aikawa and Kato, but stated that the disagreement was largely caused by the latter's not recognizing the ring closest to the vertex of the cone. Aside from this discrepancy, there was remarkable agreement between their ring radii values. Figueras (1955), who based his work largely on Partlo's technique, concluded that his results were in fair agreement with the latter.

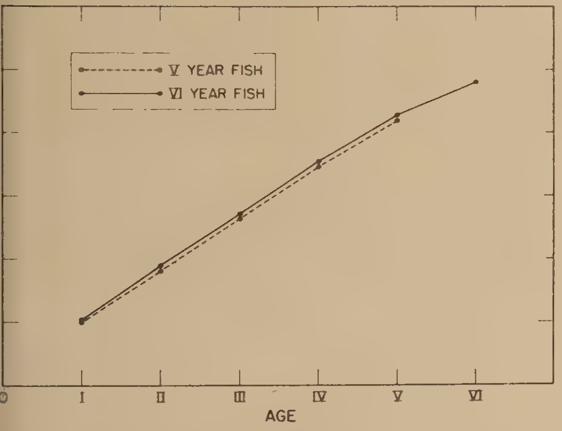
Aikawa and Kato, Figueras, and Uno, so far as can be determined, have not satisfactorily established or presented any evidence showing that the rings on the vertebrae are age rings and annual in nature. Partlo, however, hypothesized that the rings are true year marks by the following: (1) by assuming that the length groups in the size frequencies are age groups, he found that there was acceptable agreement between the m length of fish assigned to each vertebral ring-c and the mean length of corresponding leng groups in the sample, and (2) there was ag ment between the lengths of young fish calcula from vertebral measurements of older fish and observed lengths of young fish. For the lat Partlo, working with a subsample of 98 fish, fo that the observed lengths were consistently gre than the calculated lengths because the fish w captured some time after the last ring was form Partlo concluded that "from the above it se clear that the third and subsequent vertebral ri are produced annually. It is assumed, in absence of contrary evidence, that the inner rings are annual also."

While Partlo's results indicated that the ve bral rings were true year marks, it was felt t more direct evidence would be desirable. possible approach to obtaining such evidenc presented on page 357.

In this study, ring counts were not reproduc with consistency, due largely to the difficulty formulating suitable criteria for the identificat of the rings. Since it was demonstrated that th was a linear relation between the vertebral rac and the body length of the albacore (fig. 4), it difficult to make a reading without first form an opinion as to how many rings a certain-si vertebra should have. Also, in making ring me urements the selection of a ring often depended whether or not its radius fell within a cert range which encompassed all previous radii that ring. Any extreme deviation was inadv ently questioned, and a subsequent remeasurem was made on a more "reasonable" ring, which invariably found after closer scrutiny. For ample, if the investigator measures the radius the second ring at 5 mm. in a particular vertel and if all previous second-ring radii have fa between 3 and 4 mm., he re-examines the verte for a second ring which he may have "misse More often than not he will "find" the "missi ring. In fact, it was observed that "rings" co be located at will almost anywhere on the centr

Aikawa and Kato (1938) state that "where variation of the radius in comparison with ot rings is very marked, the line cannot be conside an annual ring." Figueras (1955) found tha 40 percent of the specimens he examined, the annulus as well as the succeeding annuli were closer to the center of the centrum than the sponding annuli in the remaining specimens ercent). He therefore considered the 40 nt to belong to a different spawning season discarded them from calculations of growth ments. From the above, it appears that workers also experienced some difficulty in y adhering to established criteria.

e fact that we have not been able to repro- ring counts with any reasonable consistency not in itself prove that this method of aging ore is invalid. There are other points which d also be considered. As stated earlier, no t evidence has yet been presented to show the rings on the vertebral centra are "annuli." ermore, if we examine the results presented me of the other workers, we find that the in- ents that are noted do not give either a rea- le or consistent pattern of growth. Referring kawa and Kato's results, Brock (1943) stated "it may be seen that the growth increment the age of one to that of eight is exactly the each year, resulting in a growth curve that solutely linear. This is totally at variance what is known of growth curves in general in all other species of fishes that have been ed. If the number of "age rings" bears this ionship to the length of the fish it is probable they do not represent annuli and bear no t relationship to age." Partlo's results are what similar. In figure 6 we show a plot of -length at earlier ages as calculated from 5- 6-year fish; the data were derived from Partlo 5: table VIII, p. 57). The calculated lengths



RE 6.—Calculated lengths of albacore at earlier ages sed on 5- and 6-year fish. (Taken from Partlo, 1955, le VIII.)

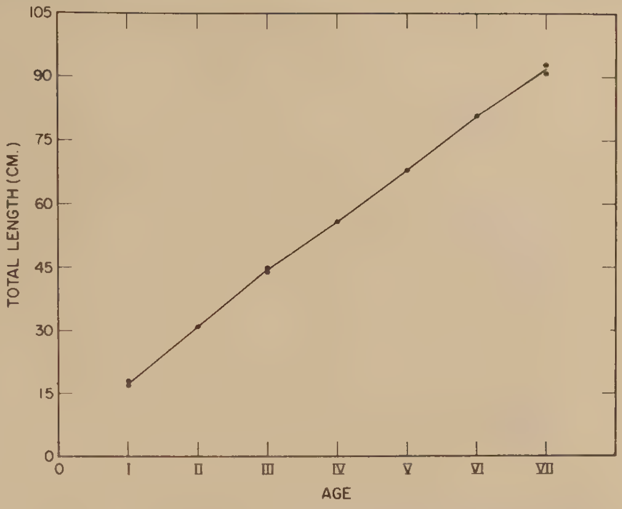


FIGURE 7.—Mean length at each age of albacore captured off northwestern Spain as reported by Figueras (1955). (Lengths given are total lengths.)

from ages 1 to 4 based on 5-year fish and the lengths for ages 1 to 5 based on 6-year fish form curves which are almost perfectly linear. The results presented by Figueras are shown in figure 7. Here again, the growth curve is remarkably linear, contrary to the general concept of growth curves.

Another consideration is that the various estimates do not appear to be consistent with growth as evidenced by tag returns. The information from this source is meager, however, and not much weight should be given it at the present time. A summary of albacore tag recoveries is given in table 2. The 5 tag recoveries which contribute information on growth are shown in figure 8.

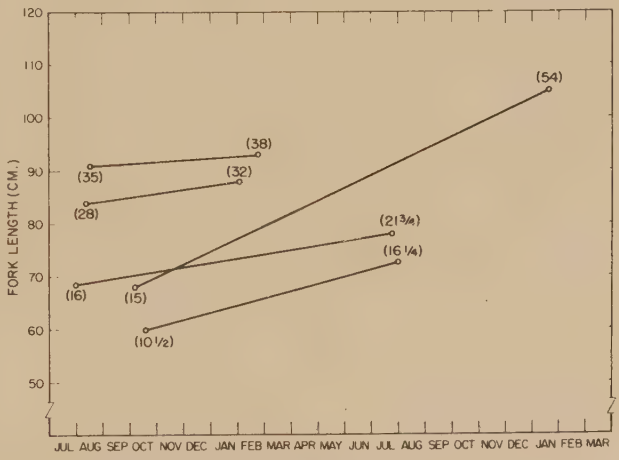


FIGURE 8.—Growth shown by 5 tagged albacore; data presented in table 2. (Body weight, in pounds, in parentheses.)

TABLE 2.—*Albacore tag recoveries reported by POFI and the California Department of Fish and Game* [1]

No.	Date of release	Locality of release	Released by	Date of recovery	Locality of recovery	Fish size	
						Release	Reco
						cm.	*c*
1	Aug. 4, 1952	33°25′ N., 118°15′ W	CF&G [2]	June 23, 1953	31°30′ N., 149°40′ E	76	-----
2	Aug. 11, 1953	Guadalupe Is	do	Feb. 2, 1954	36°40′ N., 178°12′ E	84	
3	Aug. 16, 1953	do	do	Feb. 23, 1954	30°10′ N., 178°54′ W	91	
4	Sept. 26, 1954	33°42′ N., 121°15′ W	do	Apr. 6, 1955	31°55′ N., 143°15′ E	-----	-----
5	Oct. 4, 1954	46°30′ N., 159°18′ W	POFI [3]	Nov. 28, 1955	35°45′ N., 157°39′ E	78.2	-----
6	Oct. 5, 1954	43°31′ N., 161°16′ W	do	Jan. 19, 1956	35°23′ N., 141°20′ E	68	
7	Oct. 9, 1955	42°16′ N., 147°16′ W	do	June 24, 1956	31°54′ N., 158°37′ E	63.4	-----
8	Oct. 17, 1955	44°55′ N., 144°48′ W	do	Aug. 1, 1956	31°21′ N., 117°17′ W	59.9	(16
9	July 31, 1956	44°31′ N., 174°55′ W	do	July 23, 1957	30°08′ N., 119°03′ W	68.4	(21¾

[1] The data for the California tag recoveries are derived from the reports of Ganssle and Clemens (1953), Blunt (1954), and Anonymous (1955).
[2] Department of Fish and Game, Sacramento, California.
[3] Pacific Oceanic Fisheries Investigations, U. S. Fish and Wildlife Service.

Variable growth is indicated, ranging from 2 cm. in about 6 months to 37 cm. in 16 months (4 to 28 cm. per year). The weights indicated in figure 8, with the exception of the last two recoveries (Nos. 8 and 9, table 2), are estimated weights based on the following length-weight relation:

$$\text{Log Weight} = -7.0239 + 2.87912 \text{ Log Length}$$ [1]

In terms of weight, a rough estimate of growth amounted to 6, 9, 27, 6, and 10 pounds per year, respectively, for the 5 fish shown from top to bottom in figure 8. Clearly, no conclusions can be drawn from these data. It is to be noted, however, that there are indications here of a moderately rapid growth rate, somewhat greater than the various estimates provided by the vertebral method of age determination.

It is possible, of course, that the rings on the centra are associated with growth but not necessarily with age of the fish. Unlike many of the fishes of the north temperate zone, it appears that albacore live under fairly uniform conditions by migrating to areas where food is available and where water temperature is suitable. They are not subject to extremes of winter and summer conditions as are certain fishes that occupy a more limited range. In the absence of any environmental extremes that might produce marked changes in the metabolic activity of the fish, it is quite possible that "winter" rings do not appear on the albacore's scales and vertebrae.

We have concluded that the rings on the vertebrae are probably not age rings which are laid-down annually or at such regular intervals that they can be used to tell the age of the fish; however, even if the rings were laid down rando
with respect to time, older fish in general w
be expected to possess more rings than the you
ones. Assuming this applies to the albacore,
number of rings in relation to the size of
might be used to differentiate rapidly gro
fish from slower growing individuals. Count
rings in albacore separated by sex show that am
larger fish, the females, at a given ring count
smaller than the males (fig. 9). The numbe
rings in the counts ranged from 3 to 12, and
females were represented for each count u
11 rings. Although the female albacore
parently do not grow so large as the m
having reached their maximum size at aro
112 cm. (fig. 10, also Otsu and Uchida, 1959)
ring counts indicate that the largest females
be about as old as the largest males.

A great predominance of males has been n
among the larger sizes of several species of t
(e. g. Shomura and Murphy 1955). This une
sex ratio among the larger sizes has been at
uted to "either differential mortality or differe
growth, or to combinations of the two fact
Differential availability has also been sugges
For albacore there is a similar situation,
somewhat more pronounced, for the males a
a markedly larger size than females (fig.
Returning to figure 9, fish having 7 or
rings show growth differentiation by sex,
males being the larger for each ring class.
bit of evidence suggests that after about
seventh ring, the males have a faster gr
rate than females. It is interesting to note
this apparent differentiation in growth comme
when the fish attain a length of about 90
which is the size at which albacore are beli

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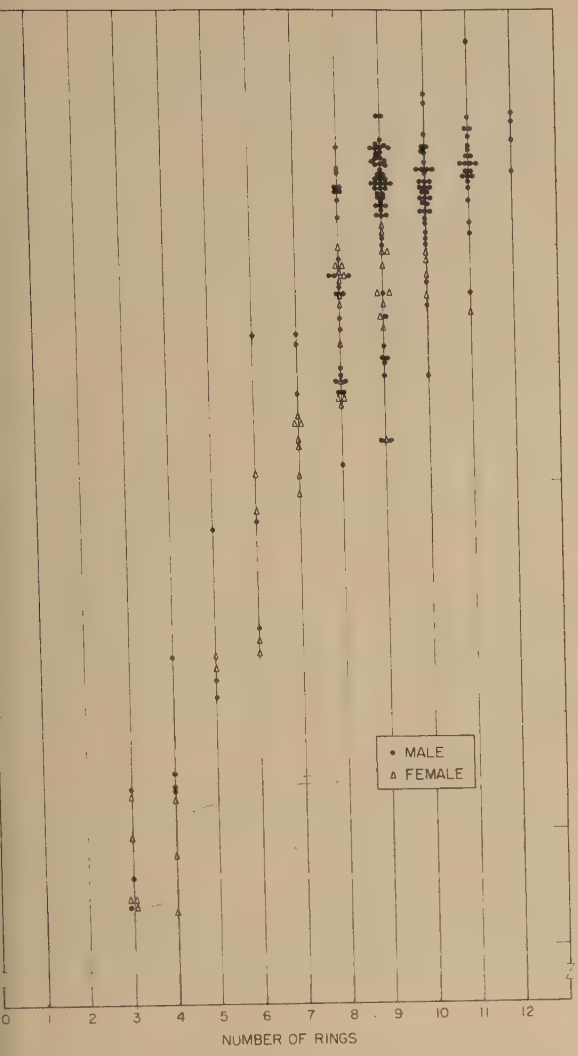
[1] Computed by POFI based on 77 fish (51–119 cm.) taken in the central North Pacific.



URE 9.—Ring counts shown by fish size and sex for one series of anterior cone readings.

each sexual maturity (Otsu and Uchida, 1959; yanagi 1955). Thus, as juveniles, both sexes m to grow at about the same rate, then upon aining sexual maturity, the males outgrow the ales, so that among the larger sizes males dominate even though the larger females are t as old as the larger males. If our assumption t the rings on the vertebrae indicate "relative " is valid, then our data suggest that this enomenon of unbalanced sex distribution among ger albacore is due primarily to differential wth, with differential mortality or differential ailability playing a possible secondary role.

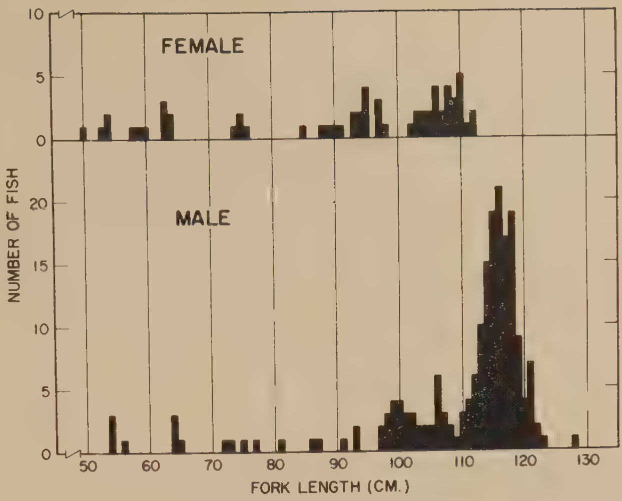


FIGURE 10.—Length and sex distribution of albacore used in this study. (The numbers of fish in smaller size classes differ from those of figure 1, which includes unsexed specimens.)

It is also apparent that differential growth is t the sole factor in operation here, since size frequencies, such as in figure 10, lack a mode of large females of a magnitude comparable to the last mode of males. We would expect to find two large modes, one of females slightly to the left of that for males, in accordance with the difference in growth rates. This is not the case. Although evidence points to differential growth as being the main factor, other factors are probably acting in conjunction to cause the apparent reduction in numbers of the larger females. Here again, we must use caution in accepting any conclusions drawn from data presented in figure 9 since, ring counts could not be duplicated with any degree of consistency. Despite the questionable validity of these data, the fact that they showed the relatively smaller females to have, in general, nearly as many vertebral rings as the larger males has prompted the authors to present this discussion as a possible explanation of the puzzling phenomenon of unbalanced sex distribution encountered among the larger sizes.

SUMMARY AND CONCLUSIONS

(1) This study is based on the examination of vertebrae and scales collected from 212 Hawaiian and 53 central North Pacific albacore. In addition to scales and vertebrae, a cursory examination was made of the operculum, dorsal and pectoral fin spines and the hypural plate for possible indications of age.

(2) The sample represents fish taken by longline, trolling, and gill nets during the period January 1955 to July 1956.

(3) None of the various structures examined revealed any markings which could be interpreted as age marks.

(4) Scales from 100 fish were examined; of these, the scales of 43 fish were considered unreadable. Samples from the remaining 57 fish varied greatly in degree of readability. A plot of the ring counts against fish size showed considerable overlapping between successive groups.

(5) Scales taken from the same fish were often of variable size. It was noted that small scales contained fewer rings than large scales, indicating that the origin of the scales was not uniform.

(6) Because of the undetermined nature of scale formation, and the fact that only about one-half of the scales were considered readable, further work with scales was discontinued.

(7) A change was observed in the shape of the caudal vertebrae with growth of the fish. Among the smaller vertebrae, from fish of about 50 to 60 cm. in length, the ratio of the length of the anterior cone to that of the posterior cone was nearly 1:1. The posterior cone was larger than the anterior in the larger vertebrae. Although the two cones of a caudal vertebra grow disproportionately, each cone in itself exhibits a linear growth with growth of the fish.

(8) In comparing independent sets of readings made by readers *A* and *B*, the highest agreement between the two readers was 44.8 percent. The best agreement between any two readings of the same reader was 38.9 percent for reader *A* and 43.9 percent for reader *B*. The most difficult rings to distinguish were those near the vertex and the margin of the cone.

(9) Although the vertebrae of small albacore were somewhat more readable than those of large albacore, it was still not possible to achieve sufficient consistency in ring counts and measurements to validate this method of age determination.

(10) The results indicated that the rings on the vertebral centra are laid down randomly with respect to time, rather than periodically. It is realized, however, that the validity of this method
of analysis is questionable, since it is based on
recognition of the last ring and since the
counts could not be duplicated with any con
ency. If our results are valid, it would ap
that the rings are simply growth marks ra
than age marks.

(11) Considerable personal bias was inadv
ently introduced into the readings and meas
ments. It was almost impossible to make a r
ing without first forming an opinion as to
number of rings that should be expected o
vertebra of a certain size.

(12) The growth increments reported by
vious investigators did not appear to give ei
a reasonable or a consistent pattern of growt

(13) The growth estimates of past investiga
do not appear to be consistent with growth
evidenced by tag returns. Although the
derived from tagged fish are meager, they indi
that albacore have a moderately rapid gro
somewhat greater than the various estim
provided by the vertebral method of age de
mination.

(14) Unlike many north temperate spe
which occupy limited environments, the albac
appears to spend its life under fairly unifo
conditions by migrating to areas of abund
food and favorable water temperature. T
these fish are probably not subject to the extr
summer and winter conditions which would ca
"winter" marks to appear on scales and verteb

(15) Although rings on the vertebrae
probably not age rings which are laid do
annually or at such intervals that they could
used to tell the actual age of the fish, it was poin
out that the rings could possibly be used to ass
the relative age, that is, older fish would h
more rings than younger fish.

(16) Results of a series of ring counts w
examined for differences between sexes. Th
was evidence that the unbalanced sex distribut
among larger albacore, with a great predomina
of males, was largely due to differential gro
which sets in with the onset of sexual matur
after which the males grow at a faster rate t
the females.

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BY RICHARD S. SHOMURA

FISHERY BULLETIN 160
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 60

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE, Arnie J. Suomela, *Commissioner*

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ABSTRACT

This study was undertaken to determine the cause of a change in species dominance in the catch of the Hawaiian longline fishery from yellowfin (*Neothunnus macropterus*) to bigeye tuna (*Parathunnus sibi*) during the period 1948–49. The available commercial catch records showed that the reversal in species resulted from a shift by the larger vessels of the fleet from fishing grounds in the leeward waters of the northern islands to grounds located in the windward waters of the southern islands. Bigeye tuna are more available to the fishery in the windward waters than in the leeward, whereas the yellowfin tuna are taken in greater numbers in the leeward areas. The bigeye season extends from October through May, whereas the best yellowfin catches are made during the summer months, June through August.

A hypothesis is given to explain the distribution and migration of the bigeye tuna in the central Pacific. Essentially, it postulates spawning in the tropical waters south of the Hawaiian Islands, a migration of young fish northward, a seasonal north-south movement of the adult population, and finally a continued southward movement to the tropical spawning grounds by adults in imminent spawning condition.

CHANGES IN TUNA LANDINGS OF THE HAWAIIAN LONGLINE FISHERY, 1948–1956

By RICHARD S. SHOMURA, *Fishery Research Biologist*

BUREAU OF COMMERCIAL FISHERIES

he Pacific Oceanic Fishery Investigations[1])FI) of the U.S. Fish and Wildlife Service studied the hydrography and productivity of central Pacific Ocean and has carried out ex- atory fishing cruises to encourage the maxi- n development and utilization of the high-seas ery resources of this area.

ne segment of POFI's task has been to gain understanding of the nature and problems of existing commercial fisheries in the central ific. Although small quantities of tuna are n in Hawaiian waters by trolling and hand- , the two major fisheries in the islands are pole-and-line fishery for skipjack (June 1951, nashita 1958) and the longline (flagline) ery (June 1950, Otsu 1954) for the larger surface tunas. In a good year (1951) the ojack fishery landed 12,900,000 pounds with a ue of $1,700,000 (Yamashita 1958). The long- fishery in 1952, a good year for that fishery, ded tunas and marlins totaling 4 million nds and valued at $1,200,000 (Otsu 1954). ough these fisheries are small in respect to total dings, their strategic occurrence in midocean kes them ideal laboratories for the study of ain problems concerning midocean tunas.

The present study of the Hawaiian longline ery was stimulated by Otsu's (1954) finding t from 1946 to 1952 there was a decline in land- s of yellowfin (*Neothunnus macropterus*) and increase in landings of bigeye (*Parathunnus*), with the reversal in dominance between 8 and 1949. The change in the bigeye landings especially noteworthy since it involved an in- ase from 12,000 pounds in 1946 to 2,200,000 nds in 1952, without a corresponding increase in the overall fishing effort as indicated by the total number of trips (Otsu 1954). The purpose of the present study was to describe the seasonal and long-term trends in the landings of the two species, and if possible, to determine cause of the fluctuations.

The basic catch data utilized in this report were supplied by the Hawaiian Division of Fish and Game, through the courtesy of Director Vernon E. Brock. T. Shimizu of the Division's staff helped to assemble the data for analysis. The longline fishermen provided valuable information on the fishery and personnel of the auction firms, Kyodo Fishing Co., United Fishing Agency, and Hawaii Fishing Co., made auction records available.

DESCRIPTION OF THE FISHERY

The Hawaiian longline fishery is the only American commercial fishery utilizing the longline method, as developed by the Japanese (Shapiro 1950), to capture subsurface tunas. The history and recent status of the fishery in Hawaii have been described by Brock (1949), June (1950), and Otsu (1954).

The longline fishery is dependent on vessels located at various ports throughout the Hawaiian Islands chain; however, the two major fleets are based at Hilo, Hawaii, about 10 vessels, and at Honolulu, Oahu, 31 to 33 vessels (Otsu 1954). These vessels range from 28 to 62 feet in length and are constructed along lines similar to the sampans used in the pole-and-line fishery (June 1951). They have a high, narrow bow with the wheelhouse and sleeping quarters located forward, leaving a spacious afterdeck of low freeboard. The latter facilitates the landing of large fish which, in the case of the marlins, occasionally exceed 1,000 pounds in weight. The vessels are

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[1] Redesignated Bureau of Commercial Fisheries Laboratory, nary 1, 1959.

OTE.—Approved for publication, July 1, 1958. Fishery Bul- 160.

generally powered by high-speed diesel engines, and since they lack mechanical refrigeration systems the catch is stored in crushed ice.

The longline is made up of a number of units of gear called baskets which are joined in a series and allowed to drift free of the vessel (June 1950). Each basket of gear is composed of a cotton mainline section from which are suspended 4 to 6 branch lines each bearing a single hook. The longline is supported at the surface by wooden, glass, or metal floats. The number of baskets fished per day varies with the individual vessel but rarely does it exceed 40 baskets. By comparison, Japanese fishermen operating on a considerably larger scale may use more than 300 baskets of gear per set (Ego and Otsu, 1952).

The average length of a trip for a Honolulu-based vessel is 8 or 9 days and a majority of the trips are made within sight of land. The gear is set in the morning and retrieved in the afternoon. During the intervening period the line is patrolled and, if the fishermen are able to recognize the presence of a hooked fish by a submerged buoy, the fish is landed and the hook reset.

Composition of the longline catch is varied and consists of a number of species of tunas and spearfishes. In addition to bigeye and yellowfin, the tuna catch includes small numbers of albacore (*Germo alalunga*), skipjack (*Katsuwonus pelamis*), and on rare occasions bluefin tuna (*Thunnus orientalis*). Among the spearfishes the most commonly taken species are the striped marlin (*Makaira audax*) and black marlin (*Makaira ampla*),[2] while lesser numbers of white marlin (*Istiompax marlina*),[3] broadbill swordfish (*Xiphias gladius*), and shortnose spearfish (*Tetrapturus angustirostris*) are taken. Other species caught on the longline include the dolphin (*Coryphaena hippurus*), wahoo (*Acanthocybium solandri*), and various species of shark. Because of the wide variety of species taken and different periods of seasonal abundance, the fishery is capable of year-round operation.

MATERIALS AND METHODS

The basic data used in this study were derived from fish catch reports submitted by members of the fishing industry to the Hawaiian Division of
Fish and Game. The form of this report used
the longline fishery has undergone several mod
cations; a sample of the present form is shown
appendix figure 1, page 105. The areas fished w
reported in code numbers indicated on a fisher
chart (app. fig. 2). The reported data were co
pared with records kept by the auctioning fir
and some adjustments made, especially for
early years when individual boat owners filled
the fish catch reports, for they occasionally co
bined the catches of several trips and report
them as a single trip. Also, the yellowfin a
bigeye catches often were not separated accordi
to species, but were combined in one or the otl
species category. In recent years the aucti
firms have filled out the forms after obtaining
essential data from the fishermen.

In addition to the sources given, more detai
information was obtained from 1949 to 1952
interviewing vessel captains. These data form
the basis of Otsu's (1954) study and have a
been utilized in this report.

Preliminary examination of the data show
that for an accurate evaluation of the fishery so
selection of data would be necessary. Descr
tion of the method used follows.

SELECTION OF FLEET AND VESSELS

Initially, the study was limited to the Honolu
based fleet, because the landings from this fl
comprised more than 80 percent of the to
Hawaiian longline landings and accessibility
the Honolulu auctioning records made it possi
to check doubtful data. Limiting the study to
Honolulu fleet does not imply that the fishing a
was proportionately restricted, since the larg
vessels at least fished throughout the ma
Hawaiian Islands group.

It was also decided to limit the sampling to v
sels operating 5 or more of the 9 years under co
sideration. This eliminated recent additions
the fleet, which were known to fish for longer
riods and with more units of gear than the old
vessels. Evidence that the bulk of the fleet v
the same throughout the period 1948 to 1956
indicated by the operation during 1956 of 23
the total of 31 vessels comprising the 1948 fle
This stability is in part a reflection of the sh
period under study and the fact that most of
vessels were comparatively new. Of the 39 vess

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[2] Called blue marlin by continental Americans.

[3] Called black marlin by continental Americans.

g from 1948 to 1956, 21, or more than half e total were launched during 1946 or 1947.

ARATION OF FLEET BY SIZE OF VESSEL

su (1954) stated that some of the Honolulu- longline vessels fished in waters around continuously throughout the year while s roamed the entire area, fishing as far as ortheastern shore of the island of Hawaii 1). The records showed that vessels fishing sively around Oahu were smaller in size (reg- d length [4] of 45 feet or less) and fished fewer of gear and fewer days per trip. Accord- the vessels were classed, based on our knowl- of the fishery, as small or large and the data for each class were treated separately.

THE TRIP AS A MEASURE OF EFFORT

ngline catch data have ordinarily been pre- d in terms of catch per 100 hooks (Murphy and Shomura, 1953). For the Hawaiian fishery, some data are available on the number of boat-days and the number of baskets fished in the early years, 1949 to 1952 (Otsu 1954), and for the years subsequent to 1955 the revised fish catch report includes the number of days at sea (app. fig. 1, p. 105). For the intervening years, 1953 to 1955, no such measures of effort are available. Even for the earlier period, 1949 to 1952, the data on the number of days fished are inadequate for a comprehensive study.

The only measure of fishing effort available for the entire period, 1948–56, is the number of trips. Thus, through necessity, the catch per unit of effort must be based on the catch per trip. To justify the trip as a measure of effort it was necessary first to determine whether there had been any changes in the length of trip during the period. Before 1952–53 some data were available on the number of days fished per trip, whereas for the subsequent years data were available on

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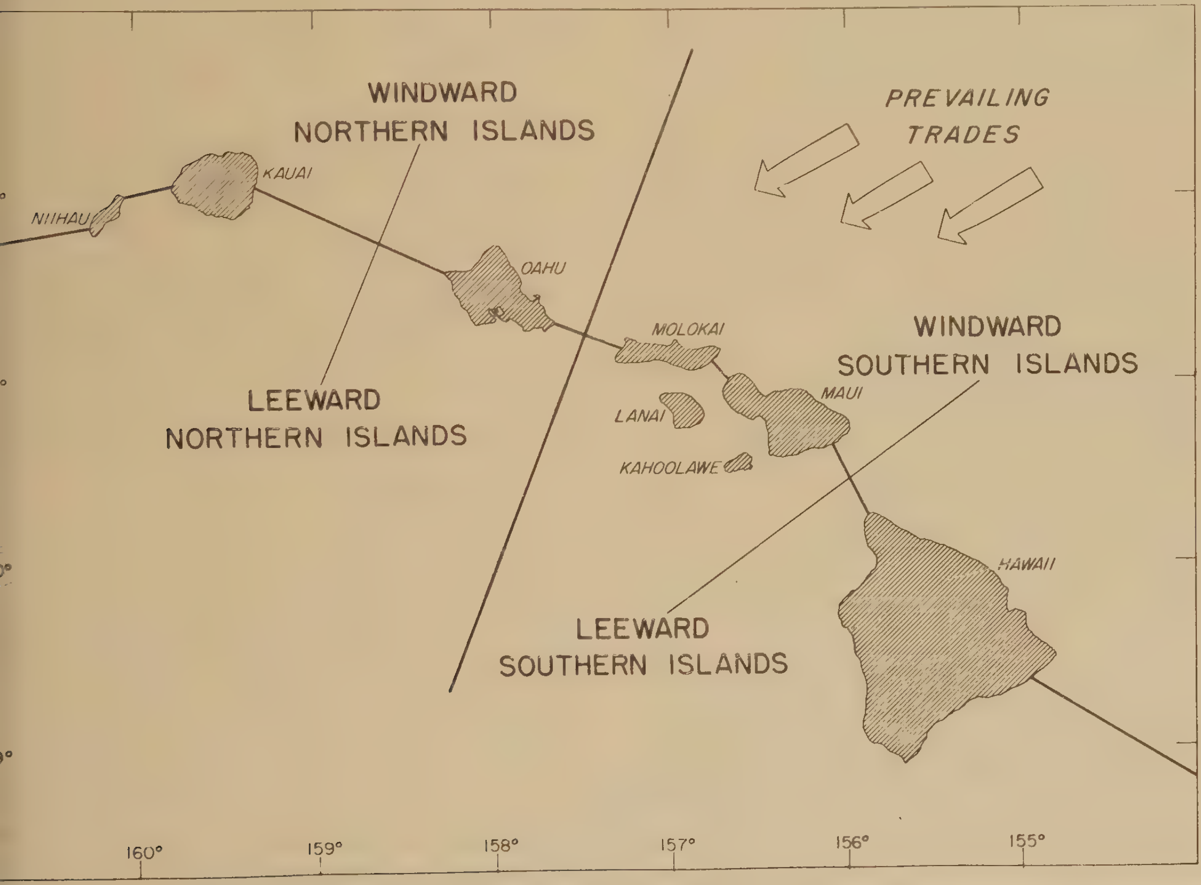
e vessel lengths were obtained from Annual Merchant s of the United States, compiled by the U.S. Treasury ment.



RE 1.—Chart of the major Hawaiian Islands subdivided into windward and leeward zones for areal studies of catch.

the number of days at sea. Excluding weather as a factor, these two measures are essentially the same for the small vessels. These vessels generally fish in the immediate vicinity of Oahu and are thus able to return to port the night of the last fishing operation. On the other hand, if the large vessels fish in the windward areas of the southern islands, they must travel from 120 to miles from the fishing grounds to Honolulu. introduces a possible differences of at least 1 depending on the area fished, between the nun of days fished and the number of days at Table 1 gives the average number of days of ing per trip for small and large vessels (the la

TABLE 1.—*Number of days fished per trip, by size of vessel, 1949 to 1956*

[Vessels selected]

	1949–50	1950–51	1951–52	1952–53	1953–54	1954–55	195
Small vessels (<45 feet):							
Number of trips	41	52	47	107	88	201	
Average number of days fished per trip	8.3	8.2	8.4	8.0	7.9	7.7	
Large vessels (>45 feet):							
Number of trips	125	132	165	165	178	321	
Average number of days fished per trip	9.7	9.0	8.4	8.6	9.2	9.4	

adjusted for traveling time). There are no evident trends in length of trip for either vessel category. For the small vessels the average trip ranged from a low of 7.7 days during 1954–55 to a high of 8.4 days in both 1951–52 and 1955–56, with an overall average of 8.1 days for the entire period. For the large vessels, the number of days fished per trip (adjusted) ranged from a low of 8.4 days during 1951–52 to a high of 9.7 days for 1949–50. The overall average length of trip for the entire period for the large vessels was 9.1 days.

Another factor that should be considered in this evaluation of fishing effort is the number of baskets fished per day. As mentioned previously, the amount of gear fished per day was related to the size of the vessels, the larger vessels fishing more baskets of gear than the smaller. This difference is reduced in importance by the separation of the fleet into the two size categories. Some data are available on the number of baskets fished per day for the years 1950, 1952, and 1955 (table 2). There is some evidence that 1952 was an atypical year (Otsu 1954). If this year is omi and only 1950 and 1955 considered, it appears the number of baskets fished per day did change materially for either the small or the l vessels. In both years the small vessels fishe average of 26 baskets of gear per day, wherea large vessels increased the amount of gear fi per day from 30 baskets in 1950 to 31 basket 1955.

TABLE 2.—*Number of baskets of gear fished per day, by size of vessel*

[Vessels selected]

	1950	1952	1955
Small vessels (<45 feet):			
Number of vessels	8	12	7
Average number of baskets fished per day	26	24	26
Range (baskets)	22–30	21–31	20–30
Large vessels (>45 feet):			
Number of vessels	17	18	16
Average number of baskets fished per day	30	28	31
Range (baskets)	21–36	25–32	24–35

A final test of the trip as a measure of fis effort is afforded by a comparison of the c per trip with the catch per 100 hooks in t periods for which both kinds of data are a able. Unfortunately, however, the only year adequate data was 1952, which has been sidered atypical. Nevertheless, a plot (fig. 2 these two units shows that the two variables

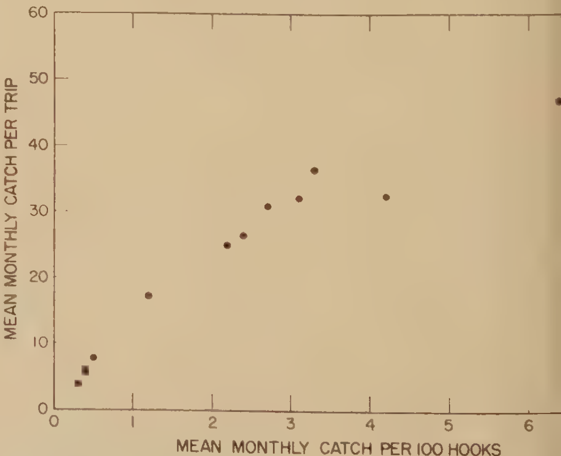


FIGURE 2.—Comparison of monthly mean bigeye catc 100 hooks and per trip in 1952.

ely correlated and exhibit a linear relation. believe, therefore, that the catch per trip is best attainable measure of availability of the species of tuna to longline gear.

ANALYSIS OF THE DATA

he total Hawaiian landings of bigeye and owfin, shown in figure 3,[5] include catches made various methods of tuna fishing, e. g., the long-, pole-and-line, trolling, and handline fishing. e yellowfin catch has shown a steady decline m 1,325,000 pounds in 1946 to 446,000 pounds 1955, whereas the bigeye catch increased from a of 199,000 pounds during the 1946–47 season a high of 2,710,000 pounds for the 1953–54 sea-. Since 99 percent of the bigeye and about 85 cent of the yellowfin are caught in the longline ery, the longline landings parallel the total dings.

The trend in yellowfin landings of the Hono-u-based vessels shows some divergence from trends in the total catch by all methods and the total longline landings (fig. 3). Despite steady decline observed in the overall catch, yellowfin landings of the Honolulu fleet re-ined at a relatively stable level, averaging ,000 pounds annually from 1948 through 1952. en in the 3 years that followed, 1953 to 1955, Honolulu landings dropped 30 percent to an erage annual figure of 275,000 pounds. Even s drop failed to keep pace with the decline of overall catch, with the result that the Hono-u landings, which in 1948 and 1949 made up ly 36 and 38 percent of the total yellowfin catch the longline fishery, averaged 64 percent dur- the next 6 years, 1950 through 1955. This lure of the trend in the Honolulu yellowfin dings to parallel that for the Territory as a ole cannot be fully explained at present; it pears to be associated with operational aspects the fishery to be discussed later in this report. should be mentioned, however, that while the ta for the Honolulu fleet have been checked and rrected by means of various sources, the same s not been done for the remaining Hawaiian gline data.

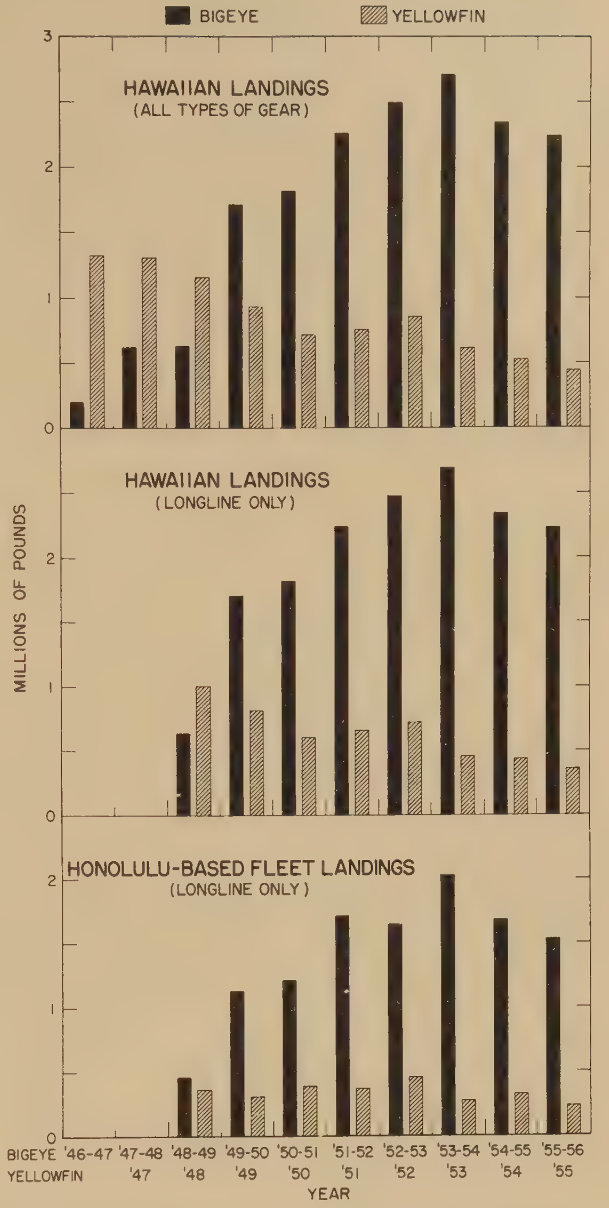


FIGURE 3.—Landings of bigeye (by fiscal year) and yellowfin (by calendar year), 1946 to 1956. (See appendix table 1.)

CATCH STATISTICS

Unless otherwise stated, the following discussions on landings and catch rates are in terms of numbers of fish rather than weight.

The bigeye catch of the selected large vessels varied directly with the landings of the entire Honolulu fleet, with a 300-percent increase between 1948–49 and 1953–54 and a decline thereafter (fig. 4). In contrast, the catch of the small

---

[5] Since the bigeye season occurs in the winter and spring nths, the annual period for bigeye extends from July of one r through June of the following year. For yellowfin the endar year is retained, inasmuch as the yellowfin landings ch a peak during the summer months.

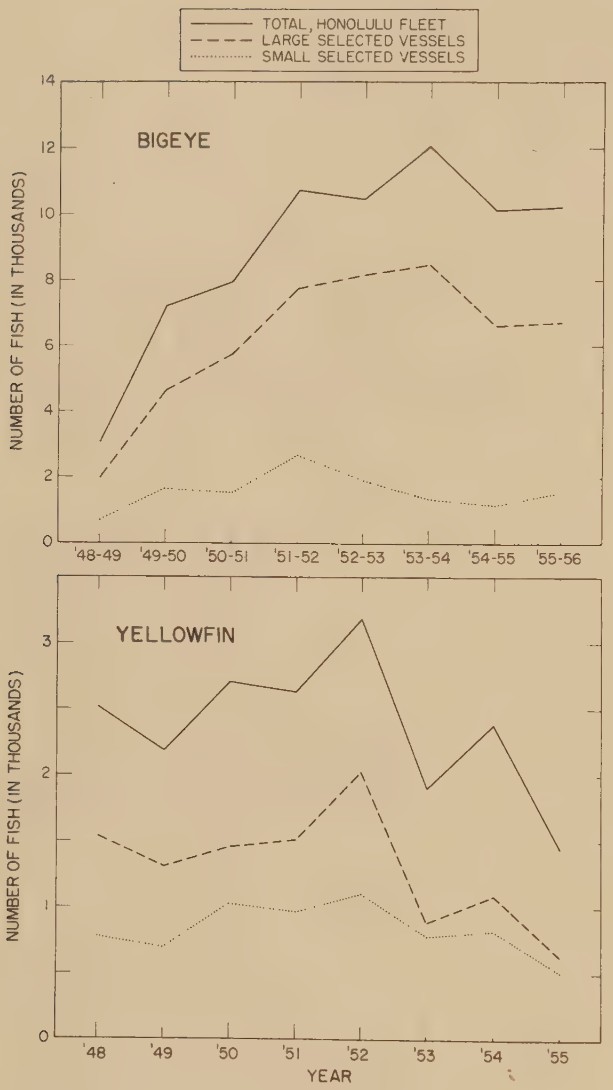


FIGURE 4.—Bigeye catch (by fiscal year) and yellowfin catch (by calendar year), by size of vessel.

selected vessels showed a slight rise from 1948–49 to 1951–52 and a decline thereafter. Thus, it appears that the tremendous increase in overall production was contributed by the large vessels.

The yellowfin landings, likewise, suggest that changes in the total catch were caused by changes in the landings of large vessels only. The most distinctive feature of the yellowfin landings (fig. 4) is the shift in relative proportion of the total catch obtained by the two classes of vessels. The proportion of the total yellowfin catch taken by the larger vessels was much higher before 1953 than it was during the last 3 years of the stu 1953 through 1955. Since this shift was coi dent with the increased bigeye catches of the la vessels, it is evident that the changes in landi are related to factors affecting only the la vessels.

FISHING EFFORT

Examination of the number of baskets fis per day and the number of days per trip indica only slight variations in these measures of effo thus, any substantial changes in the overall eff if they did occur within the Honolulu fleet, sho be revealed in the number of trips made each ye Figure 5 shows that there was a steady incre in the total number of trips from 1948–49 1953–54 and a decline in the last two seas 1954–55 and 1955–56. The increase was the res of more trips being made per boat, as shown the higher number of trips per boat-month (5), and also the result of more vessels being ad than were lost to the fleet. The latter is indica in table 3 by the increased number of trips of nonselected vessels, which presumably were rec additions.

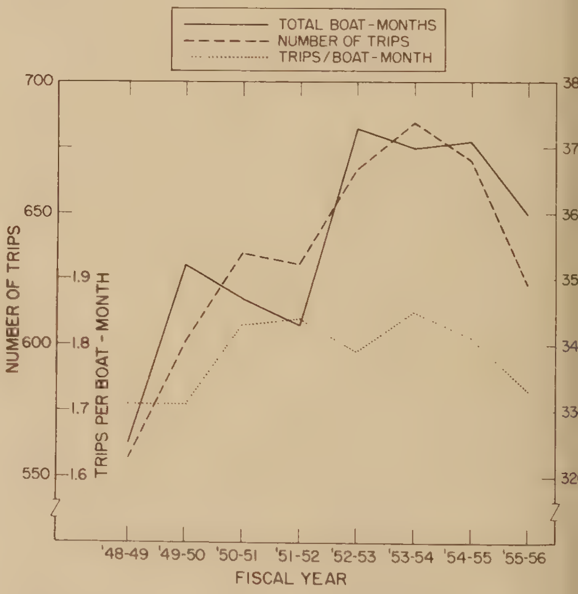
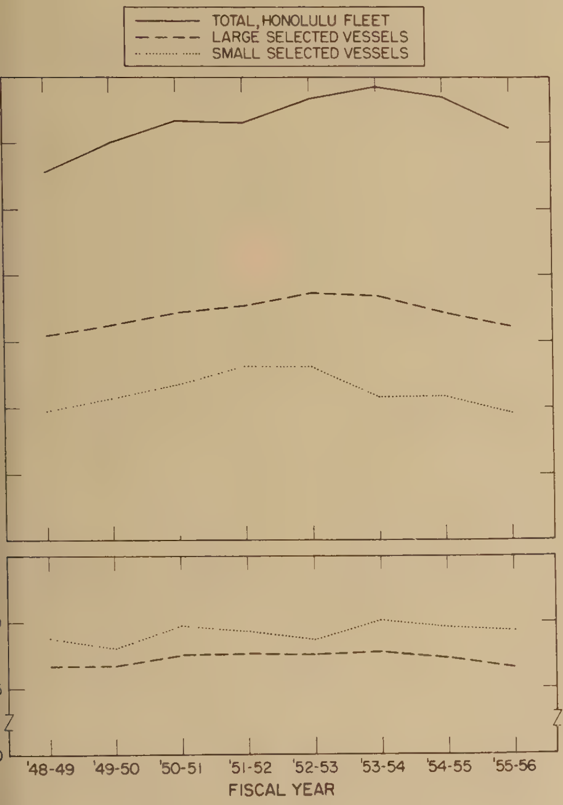


FIGURE 5.—Trends in fishing effort of Honolulu-ba fleet, 1948–49 to 1955–56.

In a comparison of the effort expended (fig. we find that both the small and large selected v sels followed the trend of the entire fleet.

TABLE 3.—*Effort expended by Honolulu-based fleet, 1948–49 to 1955–56*

Measure of effort	1948–49	1949–50	1950–51	1951–52	1952–53	1953–54	1954–55	1955–56
onths:								
cted small vessels	105	119	119	136	141	108	111	100
cted large vessels	186	195	196	199	213	207	199	194
otal	291	314	315	335	354	315	310	294
nselected small vessels	4	4	5	1	12	12	12	12
nselected large vessels	30	34	27	7	7	43	49	54
otal	34	38	32	8	19	55	61	66
ected small vessels	197	215	236	263	264	218	219	193
ected large vessels	309	327	344	354	374	370	344	323
'otal	506	542	580	617	638	588	563	516
nselected small vessels	4	6	8	2	19	24	27	19
nselected large vessels	47	53	46	12	10	73	81	88
'otal	51	59	54	14	29	97	108	107
er boat-month:								
ected small vessels	1.88	1.81	1.98	1.93	1.87	2.02	1.97	1.93
ected large vessels	1.67	1.68	1.76	1.78	1.76	1.79	1.73	1.66



URE 6.—Trends in fishing effort of small and large vessels, 1948–49 to 1955–56.

CATCH PER UNIT OF EFFORT

The marked seasonal variation in catch per unit effort for the bigeye and yellowfin tuna is wn in figure 7. The peak catch of yellowfin urred during the summer and of bigeye during the winter and spring months. Of interest is the difference in catch rate for the two species in relation to size of vessel. The bigeye catch of the large vessels was considerably higher than that of the small vessels, the difference being more evident during the later years. On the other hand, with respect to yellowfin, the large and small vessel catch rates were nearly equal, the large vessels having only a slightly higher average catch.

The increase in bigeye catches and the difference in relative fishing success by vessel size for the two species can be better illustrated by the average annual catch rates (fig. 8). The large vessels experienced a sharp increase from 6.5 bigeye per trip during the 1948–49 season to 21.9 during the 1951–52 season, an increase of about 240 percent. The catch rates in subsequent years were stable at this high level, with only a slight decrease during the last two seasons, 1954–55 and 1955–56. The small vessels, on the other hand, exhibited minor fluctuations in the bigeye catch rate during the eight seasons, but the catch remained at a relatively low level.

The yellowfin catch rates (fig. 8) varied irregularly. The small vessels had a stable yellowfin catch rate of three to four fish per trip from 1948 through 1954 and a noticeable decline in 1955. On the other hand, the large vessels experienced two levels of fishing success. The first and higher level during 1948 through 1952, when the catches ranged from four to five yellowfin per trip, and the second and lower level persisting through the last three seasons, 1953 to 1956, with a catch rate

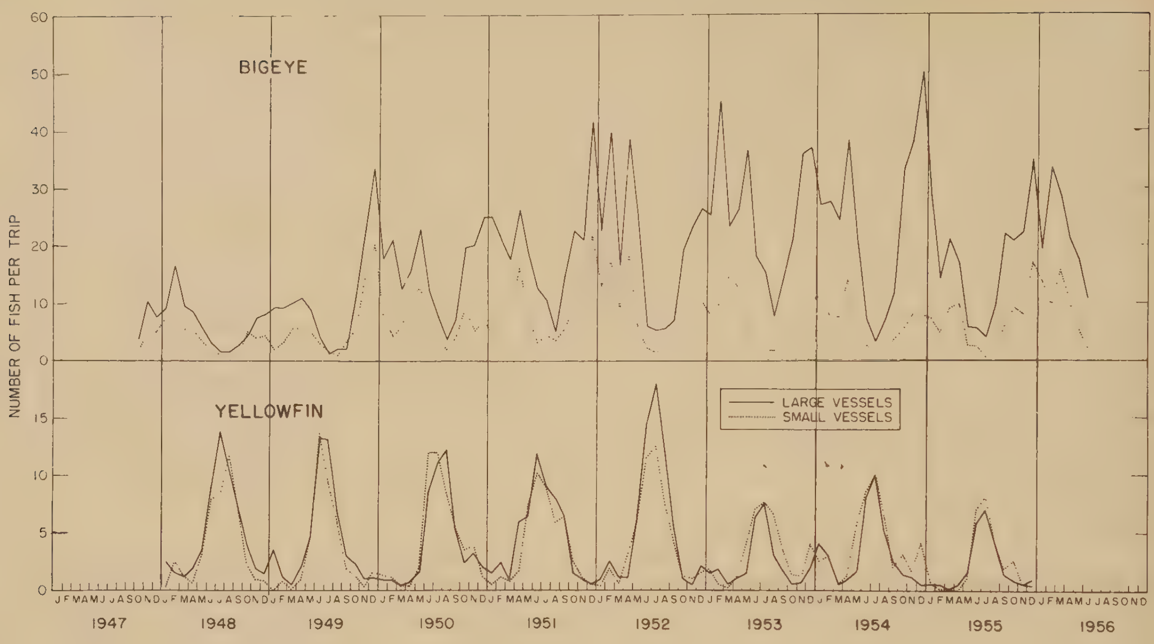


FIGURE 7.—Average catch per trip of bigeye and yellowfin tuna, by month and by vessel size.

of two to three yellowfin per trip. The most si
nificant feature of this change in level is that f
the last three seasons the catch rate of the larg
vessels was lower than that of the small vessel
This difference is surprising when it is realize
that the large vessels fished more days per tri
and more units of gear than did the small vessel

Since the factors contributing to the trip as
measure of fishing effort have been analyzed a
found to be stable, especially when vessel size h
been adjusted, the discrepancies observed must
explained by changes in availability of the specie
either by fluctuations in their actual abundance
indirectly by inherent differences in fishing succe
in the various areas fished. With regard to abun
dance, to explain the differences in bigeye catc
by the two size groups of vessels would requi
an increase in the bigeye population which did n
distribute itself uniformly throughout the fishi
areas. This is possible, but improbable, when o
must explain a simultaneous decrease in yello
fin abundance during the last three seasons—a d
crease which would be confined only to the are
fished by the large vessels. The most probab
explanation which satisfies all these varying poin

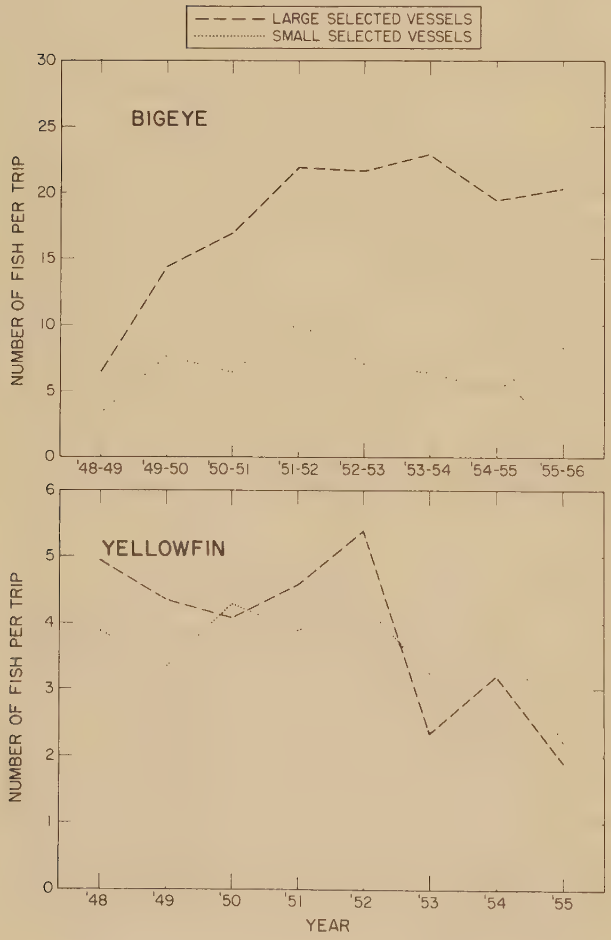


FIGURE 8.—Average bigeye catch (by fiscal year) a
yellowfin catch (by calendar year) per unit of effo
by size of vessel.

lifference in availability of the two species g localities and an increased fishing effort by rge vessels in areas containing more bigeye.

CHANGES IN FISHING AREAS AND EFFORT

ause of a limited range, the Honolulu- small vessels must confine their fishing to nmediate vicinity of Oahu. The distribution eir trips, by season and area, is given in table side from a seasonal shift in effort, there rs to be no general change in fishing area n the period studied. More than 80 percent trips of these vessels were to the windward eeward areas of Oahu, and of these the lee- areas received the greater effort. The small s fished almost exclusively in the leeward during the summer months, and although is a noticeable increase in fishing effort in indward areas during the fall, winter, and g months, the greatest percentage of the trips were made in the leeward waters at all seasons. The reason that the increase in effort was not more pronounced in the windward areas during the bigeye season may be that the small vessels prefer the calmer waters to leeward in spite of the greater availability of bigeye in the windward areas (Otsu 1954).

The distribution of trips by season and area for the large vessels is given in table 5. In general, these vessels tended to fish in the lee of the northern islands and on the windward side of the southern islands. During recent years there has been a pronounced shift in emphasis from the former to the latter area. With the exception of the winter of 1948–49, the majority of the fishing during the winter season has been in the windward areas of the southern islands. Also notable is the small yet consistent fishing effort in the windward areas of the northern islands, which could be in response to a greater availability of bigeye in these waters.

TABLE 4.—*Percentage distribution of trips of small vessels, by season and area, 1947 to 1956*

Season	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
hern Islands:										
Windward Kauai	---	---	---	13	5	5	10	---	---	---
Leeward Kauai	---	6	23	---	---	10	---	---	---	---
Windward Oahu	---	32	12	---	5	---	---	---	62	6
Leeward Oahu	---	36	65	87	89	85	62	95	33	94
hern Islands:										
Windward Maui-Molokai	---	6	---	---	---	---	3	---	---	---
Leeward Maui-Molokai	---	17	---	---	---	---	24	5	4	---
Windward Hawaii	---	---	---	---	---	---	---	---	---	---
Leeward Hawaii	---	2	---	---	---	---	---	---	---	---
Number of trips	---	47	52	54	57	20	29	22	24	16
:										
hern Islands:										
Windward Kauai	---	---	---	2	2	2	---	---	---	---
Leeward Kauai	---	17	8	---	---	2	---	---	---	---
Windward Oahu	---	4	---	---	---	4	---	---	---	---
Leeward Oahu	---	76	92	98	95	88	100	100	100	---
hern Islands:										
Windward Maui-Molokai	---	2	---	---	3	4	---	---	---	---
Leeward Maui-Molokai	---	---	---	---	---	---	---	---	---	---
Windward Hawaii	---	---	---	---	---	---	---	---	---	---
Leeward Hawaii	---	---	---	---	---	---	---	---	---	---
Number of trips	---	46	48	60	60	51	27	27	25	---
hern Islands:										
Windward Kauai	---	---	2	---	---	---	---	---	---	---
Leeward Kauai	---	12	9	2	---	---	---	---	---	---
Windward Oahu	---	12	2	---	---	12	4	9	28	---
Leeward Oahu	---	72	85	96	90	71	88	91	72	---
hern Islands:										
Windward Maui-Molokai	---	5	2	2	10	17	---	---	---	---
Leeward Maui-Molokai	---	---	---	---	---	---	8	---	---	---
Windward Hawaii	---	---	---	---	---	---	---	---	---	---
Leeward Hawaii	---	---	---	---	---	---	---	---	---	---
Number of trips	---	43	47	58	48	59	26	23	25	---
hern Islands:										
Windward Kauai	---	3	4	3	---	---	---	---	---	---
Leeward Kauai	4	9	2	---	---	---	---	---	---	---
Windward Oahu	24	14	8	3	12	14	8	29	58	---
Leeward Oahu	44	71	86	76	69	73	76	58	42	---
hern Islands:										
Windward Maui-Molokai	20	3	---	15	19	11	12	---	---	---
Leeward Maui-Molokai	8	---	---	2	---	2	4	12	---	---
Windward Hawaii	---	---	---	---	---	---	---	---	---	---
Leeward Hawaii	---	---	---	---	---	---	---	---	---	---
Number of trips	25	35	51	59	26	44	25	24	19	---

TABLE 5.—*Percentage distribution of trips of large vessels, by season and area, 1947 to 1956*

Season	1947	1948	1949	1950	1951	1952	1953	1954	1955	1
Spring:										
Windward northern islands	----------	20	3	28	41	2	19	----------	26	
Leeward northern islands	----------	23	68	29	49	42	7	----------	12	
Windward southern islands	----------	43	26	37	6	43	52	97	53	
Leeward southern islands	----------	14	3	6	4	12	21	3	9	
Number of trips	----------	70	68	86	81	81	42	35	34	
Summer:										
Windward northern islands	----------	10	18	12	43	25	----------	3	----------	----
Leeward northern islands	----------	61	75	56	36	58	10	28	17	----
Windward southern islands	----------	13	4	29	18	16	87	44	67	----
Leeward southern islands	----------	16	3	4	3	1	3	25	17	----
Number of trips	----------	69	71	84	67	89	39	32	36	----
Fall:										
Windward northern islands	----------	18	24	17	11	23	----------	----------	----------	----
Leeward northern islands	----------	55	27	41	22	10	----------	----------	----------	----
Windward southern islands	----------	18	48	41	67	65	95	97	98	----
Leeward southern islands	----------	9	1	1	----------	1	5	3	2	----
Number of trips	----------	77	82	83	85	77	43	34	40	----
Winter:										
Windward northern islands	21	24	24	14	24	19	2	----------	14	----
Leeward northern islands	15	44	17	11	10	6	7	----------	----------	----
Windward southern islands	52	31	59	74	67	75	86	100	78	----
Leeward southern islands	12	1	----------	1	----------	----------	5	----------	8	----
Number of trips	66	68	75	76	72	53	42	32	37	----

Of the four seasons, the spring distribution of fishing effort was the most erratic. Even during this season, however, the effort was concentrated in the leeward areas of the northern islands and in the windward areas of the southern islands. In the earlier years, effort during the summer was concentrated in the leeward waters of the northern islands, but during the last three summers, 1953 through 1955, it noticeably declined.

The annual effort and catch of bigeye and yellowfin by the large vessels in the windward areas of the southern islands are summarized in figure 9. The effort increased from a low of 22 percent of the total annual trips made into this area during 1948–49 to a high of 88 percent during the 1953–54 season. The following two seasons showed a slight decline. Again the significant feature both of the bigeye and of the yellowfin catch is the position of each relative to the effort expended. It is evident that bigeye fishing was more successful in this area than elsewhere, judged by the consistently higher catch percentage, than would be expected from the amount of effort expended. On the other hand, the reverse is true for yellowfin, with the catch consistently lower than the effort expended, indicating that the area is not as good a fishing ground for yellowfin as for bigeye. From this it can be deduced that yellowfin are relatively more abundant in the leeward waters of the northern islands than in the windward waters of the southern islands.

The seasonal breakdown of catch and fishing effort for the windward areas of the southern islands is presented in figure 10. The bigeye and yellowfin catch and effort by season still fol

the yearly trends. For all four seasons, the

eye catch is consistently higher than expected f

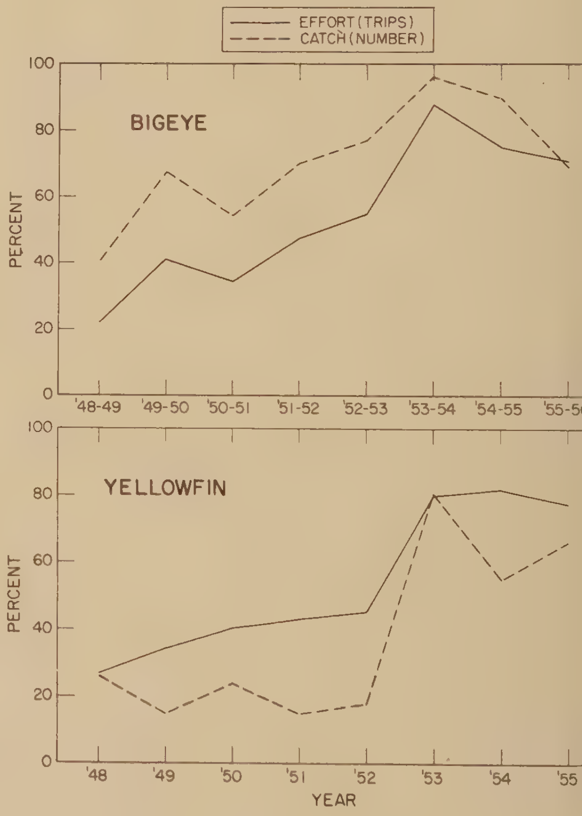
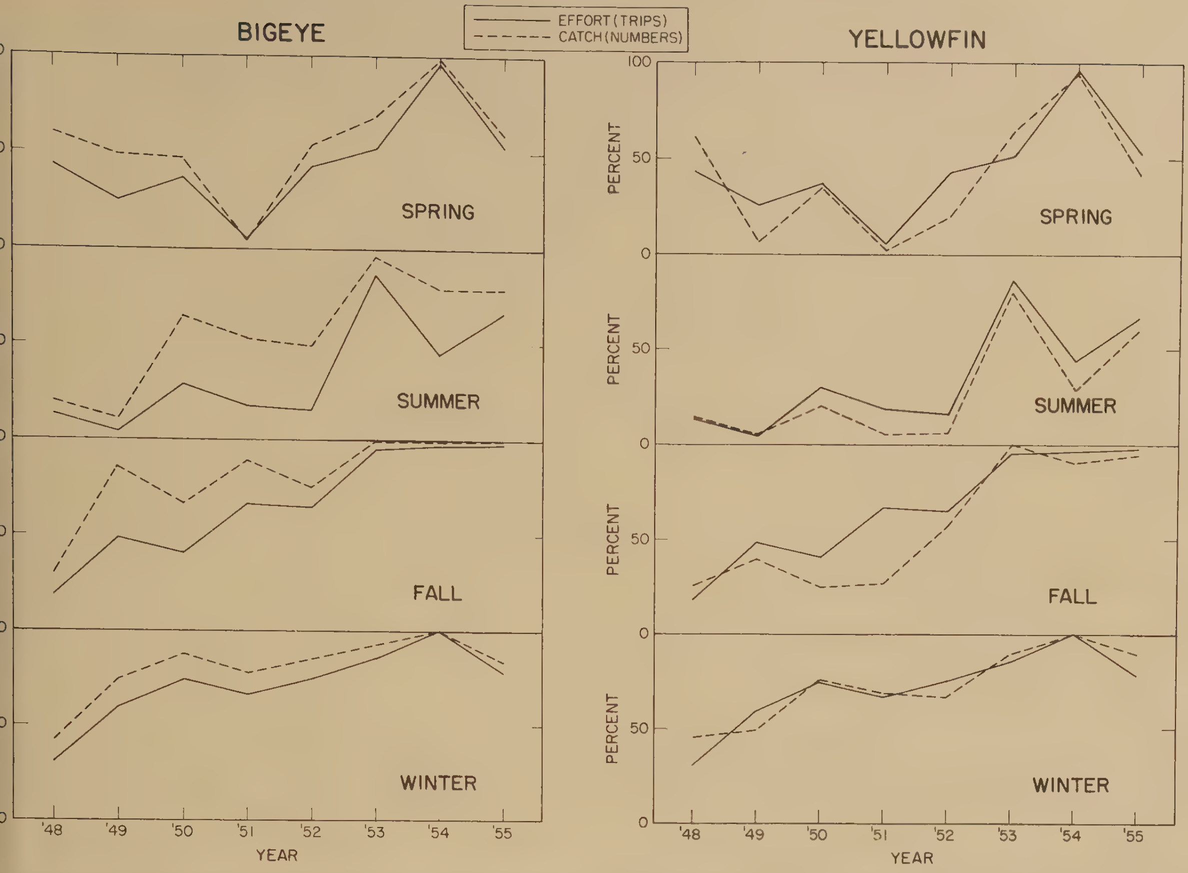


FIGURE 9.—Catch of bigeye (by fiscal year) and yello

(by calendar year) in respect to effort of large ve

in windward waters of the southern islands.

appendix table 2.)



URE 10.—Bigeye and yellowfin catch and fishing effort of large vessels, by seasons, in the windward waters of the southern islands. (See appendix tables 3 and 4.)

e amount of effort expended, whereas the reverse
true of the yellowfin catch. Thus it seems that
e differences in availability of the two species in
ese windward areas are real and not due to a
ift in effort among the four seasons.

Firm evidence of areal differences in the avail-
ility of the two species is shown by a compari-
n of the distribution of effort and the resulting
tch in the windward area by the small vessels
g. 11). To reduce the variation due to the sea-
nal shift in effort, this comparison has been con-
ed to the winter and spring seasons, December
rough May. Considering the small amount of
ta available, the possibility of an error in the
gnitude of the catches cannot be denied; how-
er, the consistently higher percentage of bigeye
ken from the windward areas for the effort ex-
nded gives evidence that bigeye were more avail-
le in the windward than in the leeward areas.
nfortunately, a similar areal comparison cannot
made for yellowfin, since the small vessels
fished almost exclusively in the leeward waters during the height of the yellowfin season.

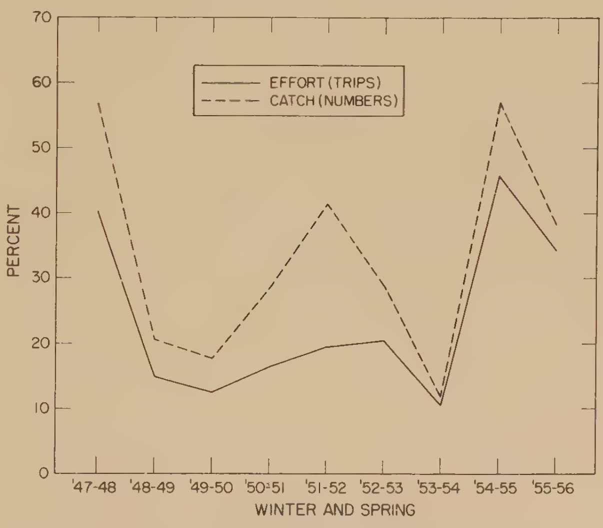


FIGURE 11.—Comparison of fishing effort and bigeye catch in windward areas by small vessels, winter and spring seasons combined. (See appendix table 5.)

In summary, the increase in landings of bigeye and the decline in landings of yellowfin can be related largely to a shift in fishing area by the large vessels from the lee of the northern islands to the windward waters of the southern islands. However, this does not preclude the existence of natural fluctuations in availability, since the catch rates of the small vessels, which did not participate in this shift, show a peak in bigeye during the 1951–52 season. Otsu (1954) points out that on several occasions during this season the catches were limited to prevent flooding of the fresh-fish market. The yellowfin, too, show natural fluctuations, as evidenced by the decline in catch rate of the small vessels during 1955.

SEASONAL DISTRIBUTION OF BIGEYE AND YELLOWFIN

A composite of the monthly average catch rates over the entire period is not the best means of depicting the seasonal distribution of bigeye and yellowfin tuna, but the lack of precise data precludes a detailed examination. This method, however, does show the seasonal trends and for this purpose the data are presented as such in figure 12.

The bigeye season can be considered to occur from October through May, when the large vessels made catches of better than 10 bigeye per trip and the small vessels from 5 to 12 bigeye per trip. The average monthly catches (fig. 7) for the large vessels showed considerable variation, which is reflected in the composite catch per trip, peaks during December, February, and Apri lows during January and March. On the c hand, the small vessel category shows only depression covering January through Ma This double peaking of the bigeye catches fo small vessels appears to hold true even for i vidual years; e.g., 1949–50 and 1953–54 (fig One possibility which could account for the points would be the inability of the vessels to because of bad weather. This would be expe to affect the catch rates inasmuch as the tr used as the unit of effort. A cursory examina of the days on which small craft warnings issued by the U. S. Weather Bureau (tabl shows that there is some correlation of low ca with bad weather. At the present time, how we are unable to make any quantitative estim of the effect of weather on catch and fishing e

The yellowfin season extends over the sum months and unlike the more gradual entran the bigeye into the fishery, the yellowfin e abruptly during the month of June (fig. This is indicated by the high catch rate of n 10 yellowfin per trip for both small and

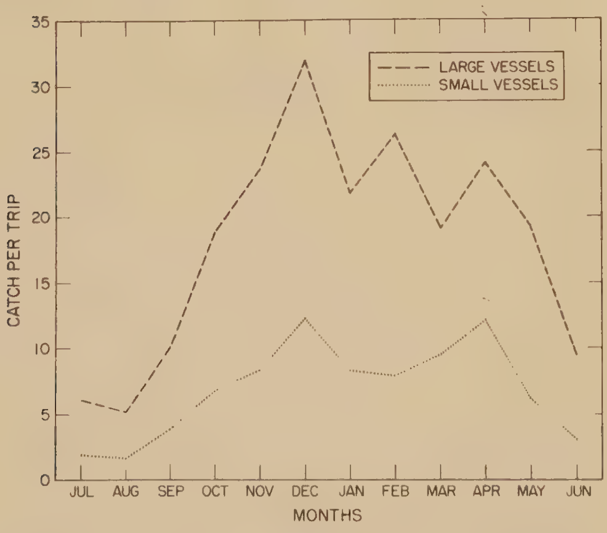


FIGURE 12.—Composite catch per trip of bigeye tuna for small and large vessels, July 1948 to June 1956.

TABLE 6.—*Number of days with small craft warni*

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1951–52	2	4	1	3	0	9	1
1952–53	0	10	1	0	4	0	0
1953–54	1	6	1	3	2	3	1
1954–55	1	3	8	1	9	5	6
1955	0	9	2				

NOTE.—Unpublished data furnished by U.S. Weather Bureau.

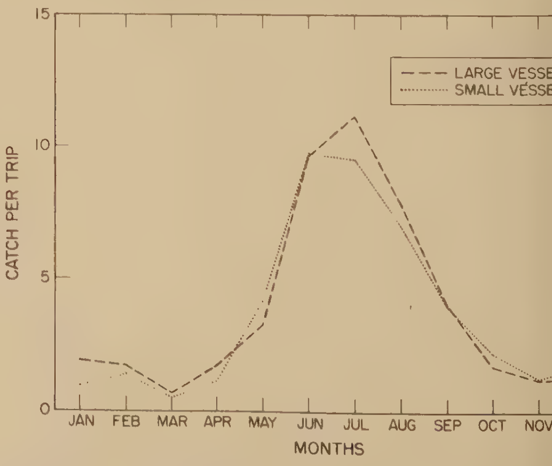


FIGURE 13.—Composite catch per trip of yellowfi for small and large vessels, 1948 to 1956.

sels during June compared with the low of ut 4 fish per trip during the previous month. e rapid decline of the catch rates during August l September, from eight yellowfin per trip to r, also suggests a rather rapid movement of yellowfin from the fishing grounds.

The yellowfin catch shows uniform single modes both small and large vessels. This absence fluctuations could possibly be due to a more form number of days fished per trip, a result the generally good weather which prevails dur- the summer months. As pointed out in the lier discussion, there are significant differences the relative fishing success for bigeye and yel- fin, related to vessel size. The catch rates for lowfin by small and large vessels were approxi- tely equal throughout the year, whereas for eye the large vessels experienced 2.5 times bet- fishing than the small vessels.

SIZE OF FISH

The Hawaiian longline fishery, by virtue of the thod of fishing, primarily exploits the large nas, a majority of the catch being composed of exceeding 100 pounds in weight. The lack small fish in the catch is not due to their absence m the area, for Moore (1951) has reported that all bigeye and yellowfin are taken in Hawaiian ters by surface-fishing methods; but more ely it is due to a differential size segrega- n of the species with depth. Bigeye and yellow- appear to spend their early life near the rface and their adult life in deeper waters, thus small fish are not available to the deep-fishing ngline gear (Murphy and Shomura, 1953).

As noted previously and shown in figure 12, od bigeye catches are made in Hawaiian waters om October through May and only during the mmer months are the catches considered poor. their work on albacore and bigeye (Honma and mimura, 1955; Suda 1954), the Japanese have own that west of the 180° meridian these two ecies undergo a latitudinal migration, being ken farthest to the north during the summer riod and to the south during the winter months. ey also present some evidence that at any given ne small fish are located to the north of the ger fish, the net result being a gradation in es with progressively larger fish to the south. me evidence of such a phenomenon in the Hawaiian fishery is indicated by the changes in average size of the bigeye (fig. 14). Despite the variability of the averages from month to month, the catch was composed of consistently smaller fish during the winter months, as is to be expected if the larger fish in a population sorted by size did move to the south during the winter.

Another interesting size variability in the catch is the consistently lower average size of bigeye taken by the small vessels as compared with those taken by the large vessels. This difference, which is most noticeable during the winter months (fig. 14), is clearly indicated in a comparison of the annual average size of bigeye by size of vessel (fig. 15). Although the magnitude of the differences is not important, the consistency of the relation, i.e., small fish being captured by small vessels, is striking. This may be confirming evidence of the size gradation with latitude, inasmuch as the small vessels operate in waters farther north than the large vessels.

The yellowfin also show considerable seasonal fluctuations in average size, with the larger fish occurring during the summer months when the catches are best (fig. 14). Unlike the bigeye, there are no pronounced differences in the annual average size of yellowfin taken by small and large vessels (fig. 15).

DISCUSSION

At present, little is known of the life histories of the various tuna species. Research has been conducted on various segments of the biology of the bigeye and yellowfin in Hawaiian waters (Brock 1949, June 1953, Otsu 1954, Iversen 1956, and Yuen 1955). Utilizing all available information, we have constructed a hypothesis to explain the presence of the bigeye in Hawaiian waters. In brief, this assumes that bigeye tuna spawn in tropical waters south of the Hawaiian Islands and that the young fish migrate to the north of Hawaii. Superimposed on this migration of the young fish are regular, seasonal north-south migrations of the adult population.

This explanation is based on the following information. Yuen (1955) established that the bigeye in Hawaiian waters are not in spawning condition, and thus their presence in the longline fishery cannot be attributed to a spawning run, such as was suggested for the yellowfin by June

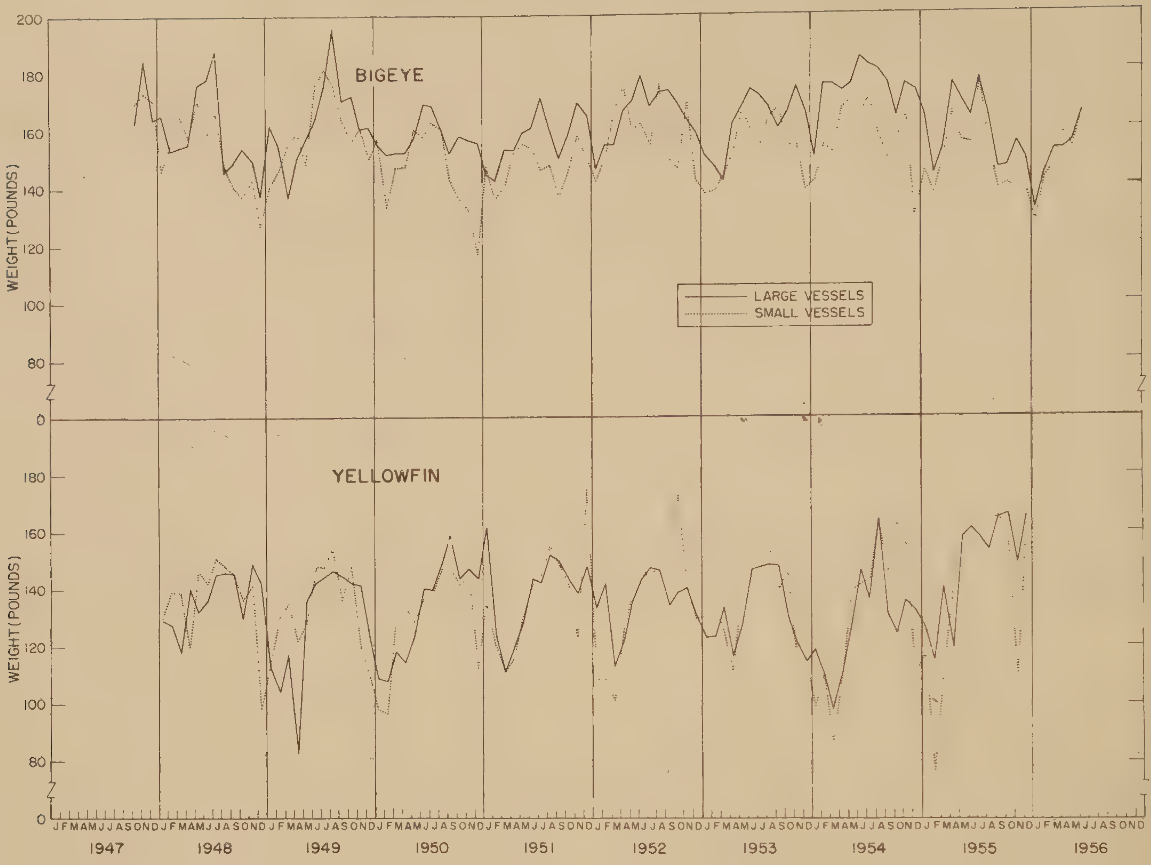


FIGURE 14.—Average size of bigeye and yellowfin, by months, in the catch of small and large vessels.

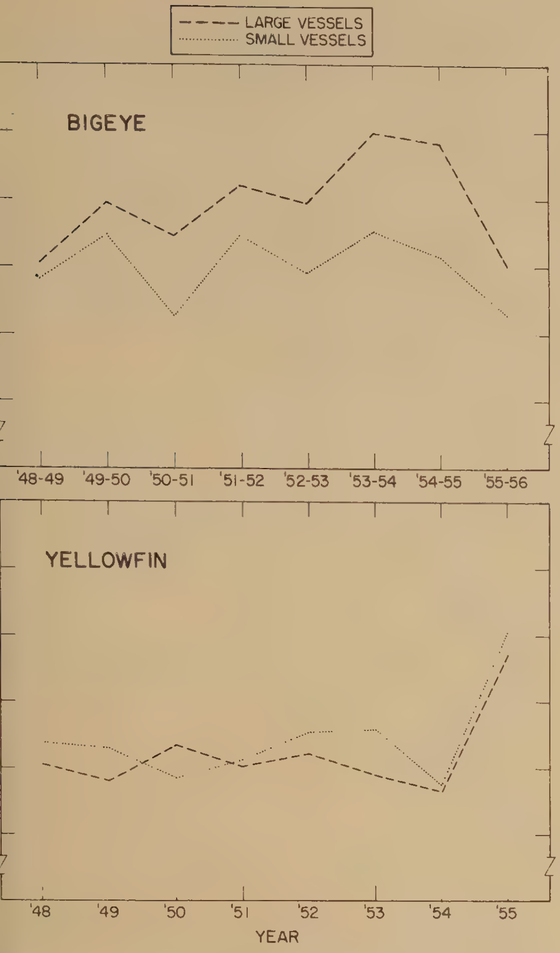
(1953). Maturation studies show that bigeye spawn more than once a year and that they have a widespread spawning area extending from the waters southeast of the Hawaiian Islands and westward to the Caroline Islands group (Yuen 1955). The presence of small bigeye in Hawaiian waters has been demonstrated (Moore 1951), but no studies have been made on the details of their distribution or seasonal variability.

According to our hypothesis, the adult bigeye population shifts southward during the winter, bringing the fish within reach of the Hawaiian fishery. Since the fish remain segregated by size, an auxiliary effect of this southern migration is to reduce the size of the fish taken in Hawaii in winter as compared with the size taken during the summer. Even during the winter it appears that the peak density of the population lies to the north of Hawaii, for Japanese vessels, specifically searching for bigeye, fish from 100 to 200 miles north of the Hawaiian Islands chain during January and February. Following the winter, t northward shift of the population leaves t Hawaiian Islands on the extreme southern frin of the distribution and the catch rates of bige drop precipitously, though a few relatively lar individuals are taken. It is during this period low bigeye catch that the large yellowfin move i the Hawaiian Islands area.

SUMMARY

1. A detailed examination of the catch recor of the Honolulu longline fleet, covering the peri 1948 to 1956, was made to determine the cau of a marked increase in landings of bigeye tu and a decline in yellowfin.

2. A study of the fishing effort expended in t fishery showed a substantial increase in the to number of trips, resulting from an increase in t number of trips per vessel and from the additi of new vessels to the fleet. The magnitude of t increase in effort was not sufficient, however,



RE 15.—Average annual size of bigeye (by fiscal ar) and yellowfin (by calendar year) taken by small d large vessels.

unt for all of the increase in bigeye landings did not explain the decline in yellowfin.

When the catch-per-trip data were classified rding to size of vessel, they showed a gener- stable catch rate for both bigeye and yellowfin he small vessels during the period under study an increase in catch per trip for the bigeye by large vessels, accompanied by a decline in yel- fin during the last 3 years (1953–55). This ergence was explained on the basis of a shift in of fishing by the large vessels. The small els, which concentrated their efforts in waters ounding Oahu, experienced uniform bigeye yellowfin catches. The large vessels, on the er hand, shifted from the leeward areas of the thern islands to the windward areas of the thern islands. The increase in bigeye catch was due to the greater availability of bigeye in the windward areas as compared with the leeward areas. The decline in yellowfin catch rates by the large vessels during the last 3 years of this study was related to the increased fishing effort during the summer in the windward areas of the southern islands, which are areas of reduced yellowfin availability.

4. Annual variations in availability not due to areal shifts in the fishery were shown in the catch rates of the small vessels. The 1951–52 season was exceptionally good for bigeye, while the yellowfin showed a decline in availability during the 1955 season.

5. The bigeye captured by the small vessels were consistently smaller than those captured by the large vessels, and the smallest bigeye were taken during the winter months.

6. A hypothesis explaining the seasonal variability in bigeye distribution has been developed utilizing the results from various studies on the life history of the bigeye and on the commercial fishery. Essentially, it assumes that spawning takes place in tropical waters followed by a migration of the small fish northward to a center of abundance located north of the Hawaiian Islands. The adult population undertakes a north-south seasonal migration, spending the winter and spring months in Hawaiian waters, where it supports a sizable longline fishery.

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APPENDIX

Appendix Table 1.—*Annual landings (pounds) of bigeye and yellowfin tuna, 1946 to 1956*

Year	Total Hawaiian landings (all types of gear)	Total longline landings	Total landings Honolulu-based longline fleet	Year	Total Hawaiian landings (all types of gear)	Total longline landings	Total landings Honolulu-based longline fleet
:				Yellowfin:			
6-47	199, 007			1946	1, 324, 767		
7-48	621, 794			1947	1, 314, 349		
8-49	632, 269	630, 935	460, 705	1948	1, 158, 111	1, 006, 460	365, 717
9-50	1, 707, 884	1, 706, 035	1, 138, 454	1949	929, 239	817, 057	307, 201
0-51	1, 820, 584	1, 819, 068	1, 215, 505	1950	720, 537	605, 315	383, 916
1-52	2, 252, 985	2, 248, 640	1, 721, 017	1951	757, 199	661, 314	368, 686
2-53	2, 496, 162	2, 473, 583	1, 648, 006	1952	855, 655	719, 326	454, 819
3-54	2, 710, 437	2, 699, 890	2, 032, 208	1953	621, 654	459, 196	272, 214
4-55	2, 346, 682	2, 340, 824	1, 680, 600	1954	525, 770	435, 551	322, 237
5-56	2, 241, 782	2, 231, 468	1, 528, 922	1955	445, 769	352, 781	229, 191

PENDIX Table 2.—*Catch of bigeye and yellowfin and fishing effort of large vessels in windward waters of the southern islands, 1948 to 1956*

I. BIGEYE (FISCAL YEAR)

	1948–49	1949–50	1950–51	1951–52	1952–53	1953–54	1954–55	1955–56
ard waters of southern islands:								
ort (trips)	62	131	110	149	133	138	101	106
tch (number)	740	3, 053	2, 919	4, 922	3, 540	4, 170	3, 179	2, 786
as:								
ort (trips)	282	319	319	314	241	157	135	150
tch (number)	1, 823	4, 528	5, 360	6, 999	4, 595	4, 332	3, 539	3, 529

II. YELLOWFIN (CALENDAR YEAR)

	1948	1949	1950	1951	1952	1953	1954	1955
ard waters of southern islands:								
ort (trips)	76	99	138	129	150	129	110	112
tch (number)	367	191	335	188	325	283	260	161
as:								
ort (trips)	280	288	340	298	328	161	134	144
tch (number)	1, 400	1, 260	1, 383	1, 267	1, 810	351	468	243

Appendix Table 3.—*Bigeye catch and fishing effort by seasons, of large vessels, 1948 to 1955*

	1948	1949	1950	1951	1952	1953	1954	1955
:								
ndward waters of southern islands:								
Effort (trips)	30	18	32	5	35	22	34	18
Catch (number)	328	337	695	76	1, 190	806	1, 166	379
areas:								
Effort (trips)	70	68	86	81	81	42	35	34
Catch (number)	545	693	1, 437	1, 670	2, 198	1, 164	1, 181	643
er:								
ndward waters of southern islands:								
Effort (trips)	9	3	24	12	14	34	14	24
Catch (number)	30	19	417	311	243	555	216	288
areas:								
Effort (trips)	69	71	84	67	89	39	32	36
Catch (number)	149	172	638	591	496	573	273	365
ndward waters of southern islands:								
Effort (trips)	14	39	34	57	50	41	33	39
Catch (number)	101	735	838	1, 541	1, 001	1, 251	1, 249	1, 048
areas:								
Effort (trips)	77	82	83	85	77	43	34	40
Catch (number)	347	856	1, 247	1, 726	1, 322	1, 264	1, 258	1, 052
:								
ndward waters of southern islands:								
Effort (trips)	21	44	56	48	40	36	32	29
Catch (number)	260	1, 358	1, 643	1, 993	1, 380	1, 329	1, 339	1, 007
areas:								
Effort (trips)	68	75	76	72	53	42	32	37
Catch (number)	611	1, 824	1, 859	2, 564	1, 602	1, 423	1, 339	1, 196

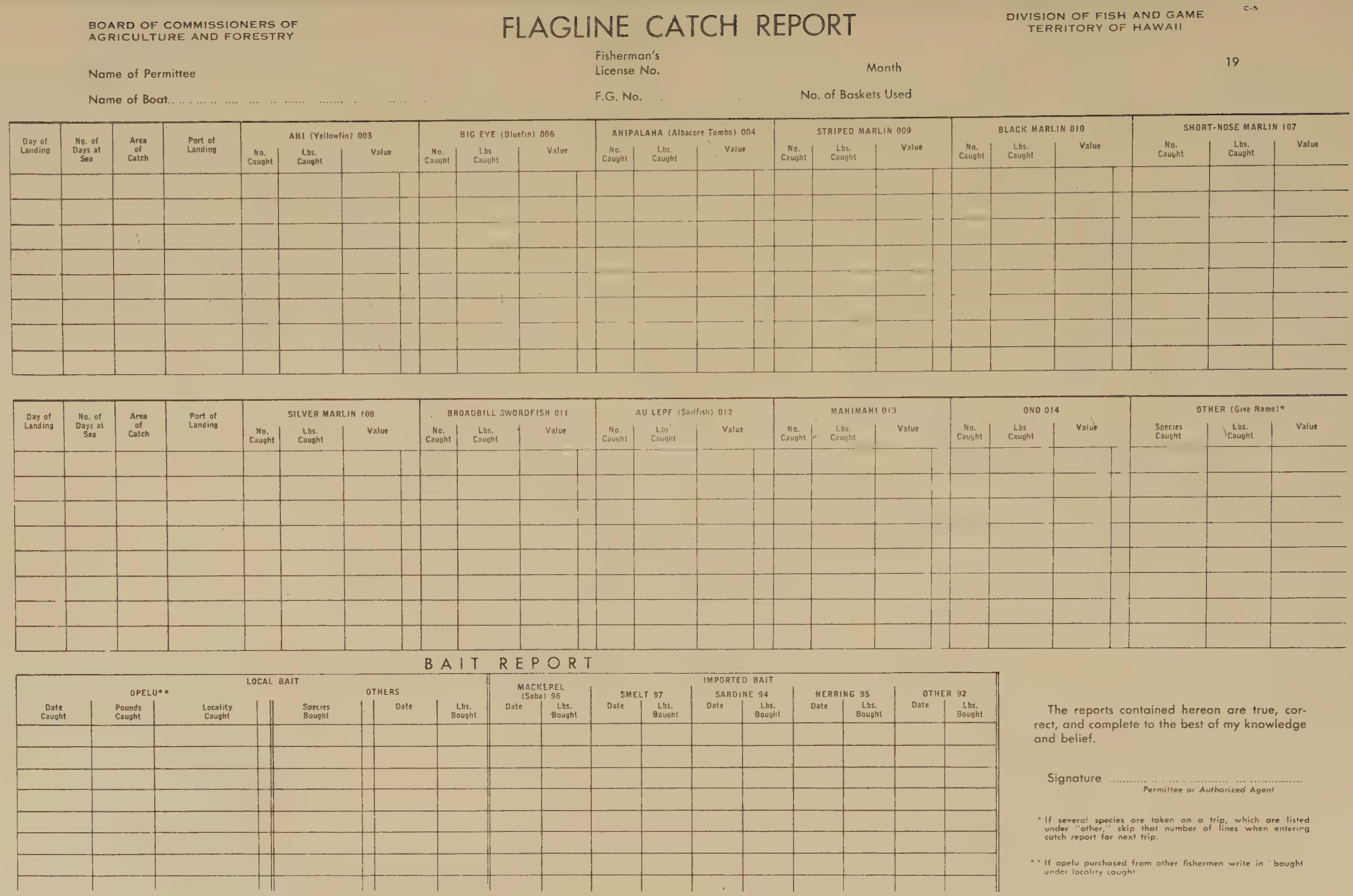
APPENDIX TABLE 4.—*Yellowfin catch and fishing effort, by seasons, of large vessels, 1948 to 1955*

	1948	1949	1950	1951	1952	1953	1954
Spring:							
Windward waters of southern islands:							
Effort (trips)	30	18	32	5	35	22	34
Catch (number)	100	10	28	6	45	22	50
All areas:							
Effort (trips)	70	68	86	81	81	42	35
Catch (number)	162	153	82	339	221	34	53
Summer:							
Windward waters of southern islands:							
Effort (trips)	9	3	24	12	14	34	14
Catch (number)	111	40	177	33	81	158	75
All areas:							
Effort (trips)	69	71	84	67	89	39	32
Catch (number)	784	803	881	608	1, 260	198	269
Fall:							
Windward waters of southern islands:							
Effort (trips)	14	39	34	57	50	41	33
Catch (number)	90	71	76	62	100	46	61
All areas:							
Effort (trips)	77	82	83	85	77	43	34
Catch (number)	341	181	307	233	176	46	67
Winter:							
Windward waters of southern islands:							
Effort (trips)	21	44	56	48	40	36	32
Catch (number)	61	33	117	57	78	100	24
All areas:							
Effort (trips)	68	75	76	72	53	42	32
Catch (number)	134	67	153	83	116	111	24

APPENDIX TABLE 5.—*Bigeye catch and effort by small vessels in all windward areas, 1947 to 1956*

[Winter and spring seasons combined]

	1947–48	1948–49	1949–50	1950–51	1951–52	1952–53	1953–54	1954–55
Windward areas:								
Effort (trips)	29	13	13	19	9	15	5	22
Catch (number)	231	83	191	279	272	221	63	255
All areas:								
Effort (trips)	72	87	105	116	46	73	47	48
Catch (number)	407	405	1, 077	977	656	766	535	447



C-5

BOARD OF COMMISSIONERS OF
AGRICULTURE AND FORESTRY

FLAGLINE CATCH REPORT

DIVISION OF FISH AND GAME
TERRITORY OF HAWAII

Name of Permittee

Fisherman's License No.

Month

19

Name of Boat.. .. ..

F.G. No.

No. of Baskets Used

Day of Landing	No. of Days at Sea	Area of Catch	Port of Landing	AHI (Yellowfin) 003			BIG EYE (Bluefin) 006			AHIPALAHA (Albacore Tombo) 004			STRIPED MARLIN 009			BLACK MARLIN 010			SHORT-NOSE MARLIN 107		
				No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value

Day of Landing	No. of Days at Sea	Area of Catch	Port of Landing	SILVER MARLIN 108			BROADBILL SWORDFISH 011			AU LEPE (Sailfish) 012			MAHIMAHI 013			ONO 014			OTHER (Give Name)*		
				No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value	No. Caught	Lbs. Caught	Value	Species Caught	Lbs. Caught	Value

BAIT REPORT

LOCAL BAIT						IMPORTED BAIT									
OPELU**			OTHERS			MACKEREL (Saba) 96		SMELT 97		SARDINE 94		HERRING 95		OTHER 92	
Date Caught	Pounds Caught	Locality Caught	Species Bought	Date	Lbs. Bought	Date	Lbs. Bought	Date	Lbs. Bought	Date	Lbs. Bought	Date	Lbs. Bought	Date	Lbs. Bought

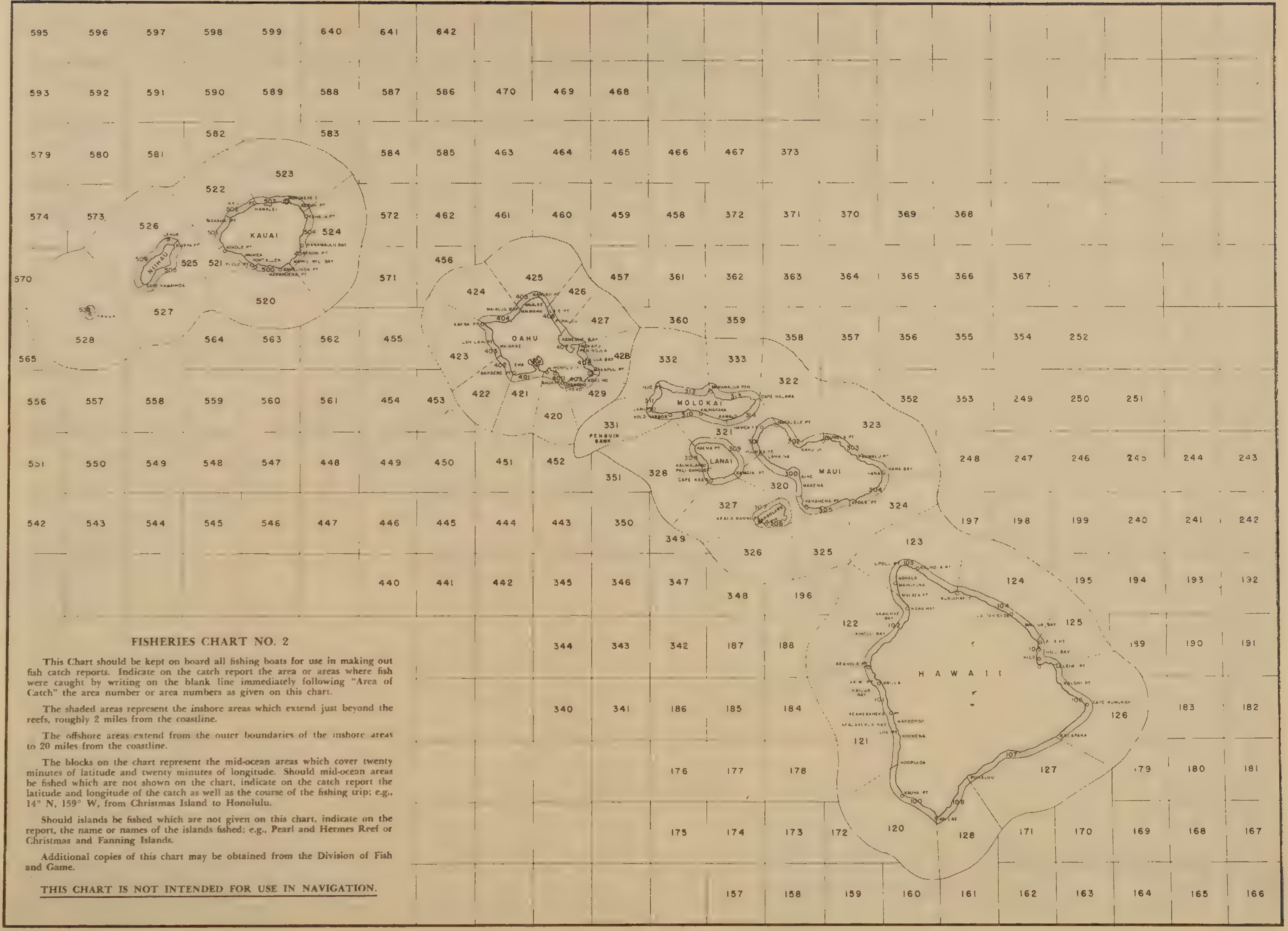
The reports contained hereon are true, correct, and complete to the best of my knowledge and belief.

Signature ....
Permittee or Authorized Agent

* If several species are taken on a trip, which are listed under "other," skip that number of lines when entering catch report for next trip.

** If opelu purchased from other fishermen write in 'bought under locality caught

APPENDIX FIGURE 1.—Presently used longline (flagline) fish catch report form.


KAUAI
NIIHAU
KAULA
OAHU
MOLOKAI
LANAI
MAUI
HAWAII
PENGUIN BANK
595 596 597 598 599 640 641 642
593 592 591 590 589 588 587 586 470 469 468
582 583
579 580 581 584 585 463 464 465 466 467 373
523
522
574 573 526 524 572 462 461 460 459 458 372 371 370 369 368
525 521 456
570 571 425 426 457 361 362 363 364 365 366 367
424 520 527
427 360 359
528 564 563 562 455 358 357 356 355 354 252
565 423 428 332 333 322
556 557 558 559 560 561 454 453 422 421 429 352 353 249 250 251
420 331 321 323
551 550 549 548 547 448 449 450 451 452 351 328 320 248 247 246 245 244 243
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349 326 325 123
440 441 442 345 346 347 348 196 124 195 194 193 132
122 125
344 343 342 187 188 199 190 191
340 341 186 185 184 126 183 182
121
176 177 178 127 179 180 181
175 174 173 172 120 128 171 170 169 168 167
157 158 159 160 161 162 163 164 165 166

FISHERIES CHART NO. 2

This Chart should be kept on board all fishing boats for use in making out fish catch reports. Indicate on the catch report the area or areas where fish were caught by writing on the blank line immediately following "Area of Catch" the area number or area numbers as given on this chart.

The shaded areas represent the inshore areas which extend just beyond the reefs, roughly 2 miles from the coastline.

The offshore areas extend from the outer boundaries of the inshore areas to 20 miles from the coastline.

The blocks on the chart represent the mid-ocean areas which cover twenty minutes of latitude and twenty minutes of longitude. Should mid-ocean areas be fished which are not shown on the chart, indicate on the catch report the latitude and longitude of the catch as well as the course of the fishing trip; e.g., 14° N, 159° W, from Christmas Island to Honolulu.

Should islands be fished which are not given on this chart, indicate on the report, the name or names of the islands fished; e.g., Pearl and Hermes Reef or Christmas and Fanning Islands.

Additional copies of this chart may be obtained from the Division of Fish and Game.

THIS CHART IS NOT INTENDED FOR USE IN NAVIGATION.

APPENDIX FIGURE 2.—Hawaiian Division of Fish and Game fisheries chart No. 2, showing the statistical areas.

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DONALD W. STRASBURG

AN INSTANCE OF NATURAL MASS MORTALITY OF LARVAL FRIGATE MACKEREL IN THE HAWAIIAN ISLANDS

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POUR L'EXPLORATION DE LA MER
VOL. XXIV. No. 2. 1959

An Instance of Natural Mass Mortality of Larval Frigate Mackerel in the Hawaiian Islands

By

Donald W. Strasburg
United States Fish and Wildlife Service, Honolulu, Hawaii

Introduction

Mass mortality among larvae of the more fecund marine fishes has been commonly hypothesized but is poorly documented. Early workers ascribed a high death rate to the yolk-sac absorption stage (FABRE-DOMERGUE and BIÉTRIX, 1897; HJORT, 1914, 1926), but recent investigators have instead indicated a considerable mortality at the larva-postlarva transformation point (SETTE, 1943; MARR, 1956, on AHLSTROM and NAIR's MS.).

The existence of a critical period in the early life history has been discredited by AHLSTROM (1954), who states that the apparent mortality might be an artifact produced by net selection, and by MARR (1956), who presents a comprehensive review of the subject. MARR concludes that there is little evidence to support the critical period theory, that records of the natural occurrence of dead larvae may be artifacts, and that where mortalities are restricted in time the causes should be obvious. He qualifies this last idea by saying that "...the chances that the observer will make the right observations at the right time and the right place are greatly reduced".

This paper documents an apparently rarely observed phenomenon, the occurrence of large numbers of dead marine fish larvae. Because of the doubt which has been cast upon a natural mortality of this sort, and because of the slight chances for observing it, it is desirable to present detailed descriptions of the fish, the sampling methods, and the environment at the time of sampling. Particular attention has been paid to the question of whether the larvae were actually dead when collected.

Methods and Descriptions

During 1956 and 1957 the Pacific Oceanic Fishery Investigations (POFI), of the United States Fish and Wildlife Service, Honolulu, tested several types of plankton tows in an attempt to devise a standard method for sampling larval tuna. On 11–13. July 1957, the POFI vessel "Charles H. Gilbert" operated in

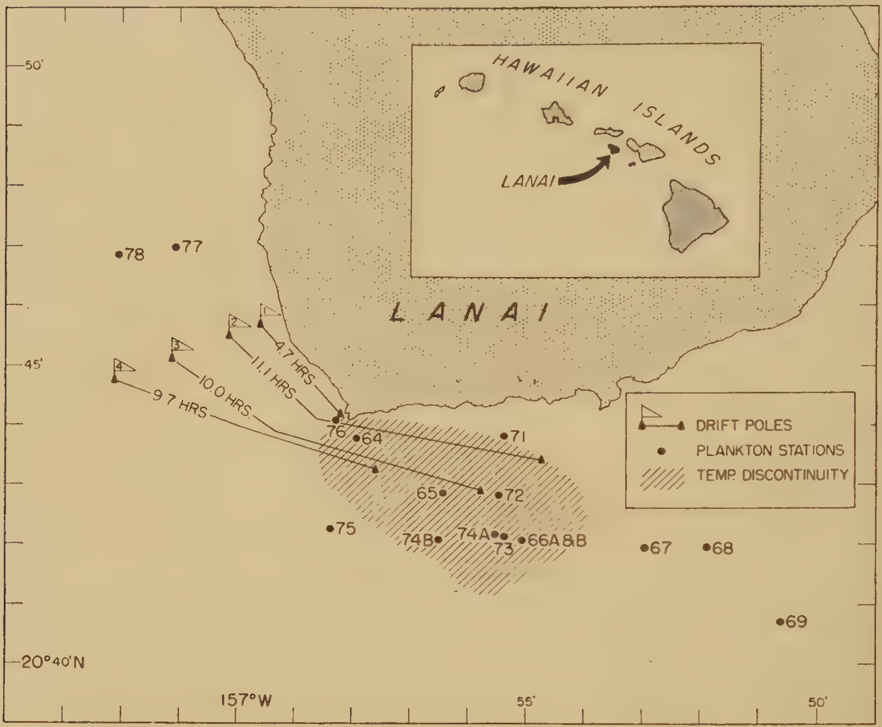
50'
45'
20°40'N
157°W
55'
50'
HAWAIIAN ISLANDS
LANAI
LANAI
•78
•77
1
2
3
4
4.7 HRS
11.1 HRS
10.0 HRS
9.7 HRS
76
•64
•71
65•
•72
•75
74B•
74A••
73
•66A&B
•67
•68
•69
DRIFT POLES
PLANKTON STATIONS
TEMP. DISCONTINUITY

Figure 1. Lanai Island showing stations from which frigate mackerel larvae were obtained, tracks of driftpoles, and area of temperature discontinuity.

the vicinity of Lanai Island, one of the smaller members of the Hawaiian chain (Fig. 1). Here a series of half-hour plankton tows was made with a 1 m (mouth diameter) net, 5 m long and constructed of nylon gauze having mesh apertures 0·66 mm in width in the body of the net and 0·31 mm in the rear section and bag. Horizontal tows were made at the surface and oblique tows from the surface to about 60 m; in the former the net fished just beneath the surface, in the latter it was lowered and retrieved at a slow uniform rate. The vessel's speed was 2·5–3·5 knots during both tows, and the course pursued was frequently circular. A current meter in the net's mouth provided estimates of the volume of water strained. The stations, catches, and other data pertinent to these operations are summarized in Table 1.

At the end of each tow the net was rinsed with salt water to wash plankton residues into the bag. The plankton was immediately transferred to a glass jar and preserved in 10% borax-neutralized formalin. Fish and fish eggs were removed from the surface samples two weeks after collection, and from the 0–60 m samples six weeks after collection, and these were also stored in 10% neutralized formalin. At no time was there any evidence of putrefaction in the samples.

The larval scombrid fishes sorted from the collections were identified with the aid of MATSUMOTO's two recent papers (1958 and MS.), with the dominant

Table 1

Larval frigate mackerel, *Auxis* sp., captured off Lanai, 11–13. July 1957, in half-hour tows with a 1 m zooplankton net

Station	Depth (m)	Date	Time tow started	North latitude	West longitude	Number of larvae	Larvae per 1000 m³	Percentage dead larvae	Surface temp. °C	Invertebrate plankton (ml/1000 m³)
64	0	11	1924	20°43·8′	156°58·0′	77	30·8	6·5	26·6	18·5
65	0	11	2059	20°42·9′	156°56·5′	288	129·1	5·9	26·4	6·5
66A	0	11	2301	20°42·1′	156°55·1′	140	58·3	99·3	26·3	4·1
66B	0	11	2337	20°42·1′	156°55·1′	173	60·4	99·4	26·3	3·9
67	0	12	0100	20°42·0′	156°53·0′	96	41·5	18·8	26·2	5·7
68	0	12	0300	20°42·0′	156°51·9′	65	27·7	4·6	26·2	6·5
69	0	12	0501	20°40·7′	156°50·6′	210	117·6	96·2	26·2	25·5
71	0–54	12	2001	20°43·8′	156°55·4′	43	35·4	0·0	25·8	40·3
72	0	12	2046	20°42·8′	156°55·5′	1557	665·8	12·8[1)]	26·5	12·4
73	0–59	12	2201	20°42·2′	156°55·5′	185	113·8	50·3	26·7	20·2
74A	0	12	2233	20°42·2′	156°55·6′	186	78·5	53·2	26·7	7·6
74B	0	12	2306	20°42·1′	156°56·6′	234	102·0	23·9	26·4	10·5
75	0–58	12	2349	20°42·4′	156°58·5′	6	3·4	16·7	26·3	18·0
76	0–62	13	0035	20°44·2′	156°58·3′	138	86·9	10·9	26·4	19·8
77	0–82	13	0133	20°47·2′	157°01·0′	30	20·9	6·7	26·2	27·8
78	0–77	13	0221	20°47·1′	157°02·0′	65	39·5	7·7	26·2	28·9

[1)] Based on a subsample of 635 fish.

form being frigate mackerel (*Auxis* sp.). The larvae of the two species of frigate mackerel occurring in Hawaii (*thazard* and a *thynnoides*-like form) are not as yet separable, and it is not known whether more than one species occurred in the Lanai collections. Not only were large numbers of frigate mackerel larvae obtained, but in many cases the specimens appeared to have been dead prior to capture. The correctness of this supposition is discussed in the following paragraphs.

Assessment of Mortality

When first examined the larval frigate mackerel were viewed against a black background with direct, overhead illumination. It was immediately noticeable that there were two distinct types: clean-cut larvae of normal appearance, and imperfect specimens with signs of physical deterioration. Further examination led to the hypothesis that these types represented fish which were alive and dead, respectively, just prior to capture. With this idea in mind all specimens were examined against a black background, and categorized as living or dead on the basis of the following characteristics: —

Living – flesh cream-coloured, opaque; vertebral column visible as a grey line separating epaxial and hypaxial musculature; visceral mass and anus turgid; eyes, jaws, and gill arches usually intact; body frequently contorted.

Dead – flesh grey, somewhat translucent; vertebral column invisible; visceral mass often lacking, when present both it and anus flabby; eyes typically absent; lower jaw prognathous; gill arches distorted; body straight.

Typical representatives of these two types are shown in Figure 2. The colour and transparency of the flesh of the "dead" fish suggest decomposition, as does the lack of eyes and distortion of the gill arches. However, the latter effects

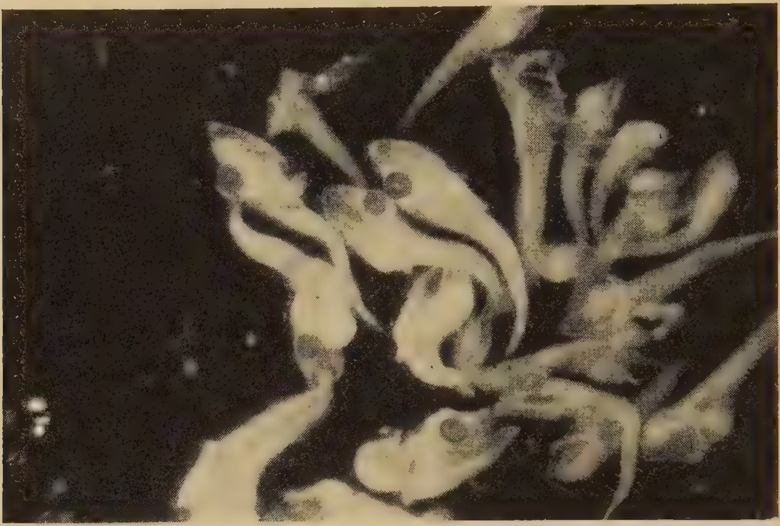

Figure 2. Typical larval frigate mackerel from Lanai. The light coloured specimens to the left were regarded as living, the darker fish to the right as dead.

could also be caused by net damage. The straightness of the body, which stands in marked contrast to the contorted attitudes of the most perfect and fresh looking larvae, implies considerable muscular relaxation, a phenomenon associated with death, at the time of preservation. The loss of the visceral mass could similarly be related to death and putrefaction, with the bloated viscera rupturing the body wall and ultimately tearing free. An increase in buoyancy, brought about by the accumulation of the gases of decay, is a logical mechanism by which dead larvae would remain at the surface to be collected. It should be noted that these larvae do not have swimbladders.

Before accepting the above hypothesis it is necessary to examine several possible causes for the condition of the damaged and "dead" larvae. MARR (1956) noted that damaged larvae were common in plankton samples containing hard, sharp animals such as pteropods, and that another common source was contamination from a previous haul owing to inadequate washing of the net. To investigate the damage caused by hard-bodied animals, counts were made of all pteropods occurring at Stations 66B and 71, where frigate mackerel mortality was 99·4 and 0·0%, respectively. The total number of pteropods was 22 for Station 66B, and 115 for Station 71, a reverse trend from what would be expected if pteropods damaged the larvae. Neither was damage proportional to the invertebrate plankton volumes obtained (Table 1), for no correlation was found when the plankton volumes were plotted against percentage mortality. It was concluded that the presence of other organisms in the catch had little to do with the condition of the larval frigate mackerel.

As stated earlier, the net was washed between tows so that few organisms could have persisted to contaminate later samples. Examination of the stations listed in Table 1 reveals that a catch showing a heavy mortality sometimes followed one of numerous normal fish, but that several stations were notably at variance with this. Thus Stations 66A and 66B were successive and had

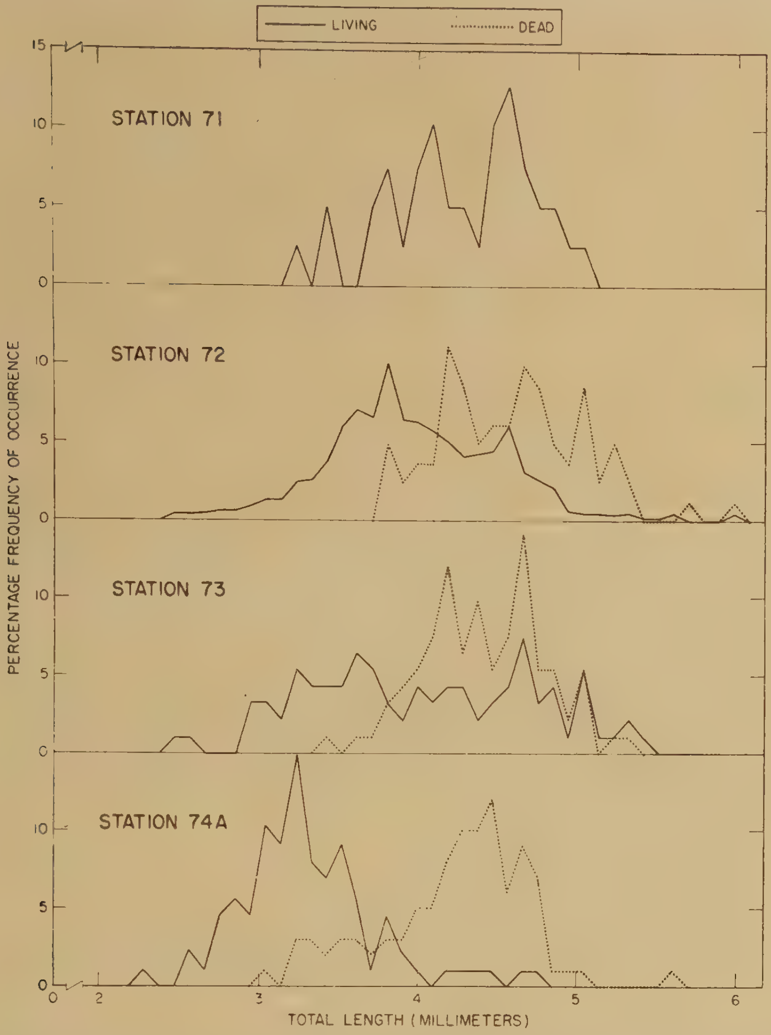

Figure 3. Length-frequency distribution of frigate mackerel at stations showing heavy mortality. Data derived from following numbers of fish: Station 71, 39 living; Station 72, 554 living, 81 dead; Station 73, 92 living, 92 dead; and Station 74 A, 87 living, 99 dead.

equally high mortalities, as did Stations 73 and 74 A, and Station 76 had an appreciable mortality, yet followed Station 75 where only 6 larvae were captured.

Another line of evidence tending to discredit contamination deals with the length-frequency distribution of the living and dead larvae. Here, total length was measured with the aid of an ocular micrometer, using the snout tip and the end of the longest caudal ray as reference points. Measurements were made to the nearest micrometer subdivision (0·095 mm) and subsequently converted to millimetres. Rather complete overlaps were found in length frequency for

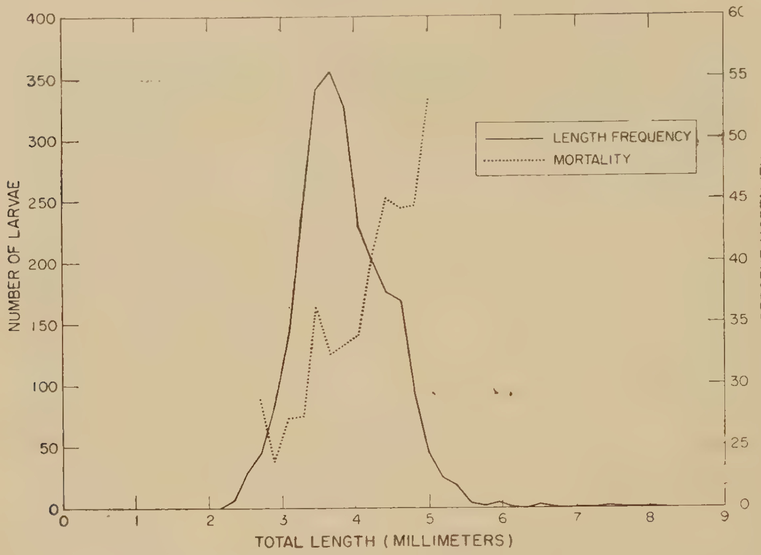

Figure 4. Length-frequency distribution of frigate mackerel, and percentage dead at various lengths. Length data derived from 2561 living and dead specimens; mortality figures based upon 2459 specimens.

Stations 64 through 69, but for Station 71 through 78 there was evidence that the dead fish were not from the same length populations as the living ones. Figure 3 shows that although the dead larvae taken at Station 72 could have been carry-overs from Station 71, there is little likelihood that those in Station 73 persisted from Station 72, or that those in Station 74 A were remnants from Station 73.

If the occurrence of the dead larvae was actually due to contamination then one would expect the mortality at a given length to be proportional to the number of fish of that length. That this is not so is shown by Figure 4, which depicts the mortality at each length category (a subsample was studied from Station 72, and mortality was not calculated for the smaller samples). Mortality is seen to increase with size, with fish about 5 mm in total length being most severely afflicted. As noted by STRASBURG (MS.), tuna larvae of 5 mm and larger are not often caught in plankton nets, probably because of their increased ability to avoid the net, so that their present capture may have been possible because they were dead.

A simple experiment was performed to determine if decomposing larval tuna would ultimately have the appearance of "dead" larvae. The plankton from several night surface tows was frozen after collection, thawed in the laboratory, and sorted in dishes placed in bowls of ice. Twenty-seven larval tuna (19 *Neothunnus macropterus*, 7 *Auxis* sp., and 1 *Katsuwonus pelamis*) were obtained, and these were examined and their appearance noted. Seven representative specimens were then preserved in formalin and the balance allowed to decompose in dishes of sea water over a period of nearly 47 hours at room temperatures of 23°–29°C. The decomposing specimens were re-examined at intervals and samples were preserved periodically. When all specimens had been preserved they were set aside for one week and then categorized as living or dead using

Table 2

Effects of decomposition upon appearance of larval tuna

Time sample preserved	Appearance of larvae (L = living, D = dead, L^1 and D^1 are intermediates)
10 min.	4 L, 1 L^1, 1 D^1, 1 D
3 hr., 10 min.	2 L, 2 D^1
6 hr., 45 min.	2 D^1, 2 D
22 hr., 20 min.	1 L^1, 3 D
30 hr., 55 min.	1 L^1, 4 D*)
46 hr., 45 min.	1 L, 2 D*)

*) Specimens badly deteriorated.

the criteria listed above. The effects of decomposition upon the appearance of these larvae are shown in Table 2 from which it is apparent that a "dead" appearance was generally acquired after 3–6 hours of decomposition. Some specimens, however, had a "living" aspect after 31 hours, and an unusually large fish (a 9·5 mm *Neothunnus macropterus*) appeared "living" after nearly 47 hours. Another larva appeared "dead" both at the start of the experiment and after a week in formalin.

Decomposition seems to be the agent responsible for the difference in appearance between the living and dead specimens. In this connexion it should be noted that decomposition in still water did not result in loss of the visceral mass, although it did cause a considerable loosening of that structure. Presumably the dead specimens taken at sea lost their viscera from agitation by waves or by the plankton net. It was also of interest that no experimental specimens bloated as decay progressed. This does not necessarily eliminate bloating-induced flotation as the mechanism responsible for dead larvae being caught at the surface, for apparently some fish decompose without rising to the surface (DENCE, 1956).

Causes of Death

In natural conditions an increase in the abundance of organisms is thought to be depressed by a system of checks and balances: predation, disease, competition, and the suitability of the physical environment. Predation can be excluded from the present case because it would have resulted in the recovery of no larvae or of larvae with some signs of natural mutilation. The agency involved instead appears to be generalized, for it afflicted a relatively wide size range of larvae, and was apparent over a distance of 12·5 miles and through a time interval of 29 hours.

Gross external examination of about 300 specimens (living and dead in about equal numbers) revealed no signs of disease, but it should be remembered that disease would not necessarily have external manifestations, and that slight symptoms could have been overlooked. No parasites were encountered on the gills, integument, or mouth surfaces, nor were any found internally.

About 500 living and dead larvae were examined for ingested food, with about 50 being dissected and the remainder viewed against a strong light which rendered them quite transparent. No food items were found in the digestive tract of any specimen, but in two cases the intestine was so bloated that the body wall bulged laterally, and when opened was found to be filled with viscid white fluid. Those fish examined for the presence of food had been captured in the evening, at night, and at dawn, so that the lack of food in their stomachs may only mean that young frigate mackerel are daytime feeders. As can be seen from Table 1, no daytime samples were collected.

There is no way of determining if the mass death was caused by starvation. All specimens were past the "critical" period of yolk-sac absorption, and presumably had already begun feeding on planktonic food. Neither the type of food consumed nor its availability during the sampling period is known. There should be competition for food between individual frigate mackerel larvae and possibly also between them and various other members of the zooplankton. The invertebrate portion of the latter, however, was not over abundant in the samples collected, for the mean catch, 16·0 ml of plankton per 1000 m^3 of water strained was equal to, or less than, comparable Hawaiian plankton samples reported upon by KING and HIDA (1954, 1957). Thus if starvation were the cause of death it might have been induced by intra-specific competition or lack of a critical supply of the right sort of food.

POFI is continuing its studies of the Lanai area for several reasons, one of which concerns a water temperature discontinuity in the region from which the present samples came (Figure 1). In the discontinuity zone surface temperatures varied as much as 1·5°C in approximately one mile, and the surface was frequently characterized by floating terrestrial debris. As pointed out by MATSUMOTO (1958) and STRASBURG (MS.), larval frigate mackerel migrate to the surface at night, and would then be in a region of rapid temperature change at Lanai. Figure 1 also shows the discontinuity area to lie in the path of a current flowing south-easterly or easterly at a speed of about 0·5 knots.

It is to be noted that the upstream stations (Nos. 64, 65, 75–78) had frigate mackerel mortalities ranging only from 5·9 % to 16·7 %, whereas at certain downstream stations (Nos. 66 A, 66 B, 73–74 B) mortality ranged from 23·9 to 99·4 %. Although not true of all stations, it would seem that passage through the discontinuity area was directly related to mortality.

The location of the principal death site can be roughly calculated by means of the known decomposition rate and current speed. A 0·5 knot current would flow 1·5–3 miles in the 3–6 hours necessary for larvae to assume a "dead" appearance by decomposition. In the case of the stations showing the heaviest mortality (Nos. 66 A and B), this could place the death site at or near the north-western edge of the discontinuity area. Current drift could also account for the appearance of large numbers of dead larvae downstream from the discontinuity area (Station 69). The lack of high mortality at such stations as 67, 68, and 72 is presently inexplicable.

Summary

1. The mass death of larval marine fish has been the subject of much speculation but has remained largely undocumented. The present paper deals with a series of Hawaiian plankton samples containing 3,493 larval frigate mackerel (*Auxis* sp.), large numbers of which were thought to be dead before capture.

2. The appearance of the dead larvae was markedly different from that of the living fish, and these differences could logically be associated with death prior to capture. Deterioration of the dead fish was probably not brought

about by contact with hard, sharp organisms, or by the fish remaining in the net between hauls. The length-frequency distributions and the percentage mortality of various length groups also discredited contamination of this sort. Fresh larvae allowed to decompose attained a "dead" appearance in from 3 to 6 hours.

3. The definitive cause of death could not be determined. There were no signs of predation, disease, or parasitism, but starvation could not be definitely excluded as a factor. It was tentatively hypothesized that the mass death was brought about by passage through an area having marked discontinuities in its surface water temperature.

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NOTES ON THE DIET AND CORRELATING STRUCTURES OF SOME CENTRAL PACIFIC ECHENEID FISHES.—Although the results of a stomach analysis of echeneid fishes have existed in the literature for over 100 years they have been largely overlooked by ichthyologists. Thus Bennett's (*Narrative of a whaling voyage . . . 2:271*, 1840) finding of "... small marine insects, shrimps, and fragments of delicate shells" in the stomachs of *Remora remora* is not widely known, and the food of this and related species is instead generally described as scraps from the meals of its hosts (sharks, marlin, sea turtles, etc.).

While the relation between an echeneid and a larger animal has become almost a classic example of commensalism, it is not clear with whom the idea originated. It was frequently mentioned at the turn of the century (Holder, *Sci. Amer. 82(21):331*, 1900; *ibid. 93(9):163*, 1905; Geare, *ibid. 87(5):73*, 1902) and has persisted until the present (Irvine, *The fishes and fisheries of the Gold Coast, pp. 211–2*, 1947; Norman, *A history of fishes, pp. 70,245–46*, 1949; Norman and Fraser *Field book of giant fishes, p. 176*, 1949; Smith, *The sea fishes of southern Africa, p. 340*, 1950; Bigelow and Schroeder, *USFW Serv. Fish. Bull. 53(74):484, 487*, 1953). Some of the above authors as well as Jordon (*Fishes, p. 679*, 1907) and Boulenger (*Teleostei, Cambr. Nat. Hist. 7:691*, 1922) state that echeneids are also carnivorous upon small fish such as sardines and herring; in this case the hosts merely serve for transportation to the feeding grounds at which the echeneids detach and actively pursue their prey. Smith (*op. cit.*) cites an earlier worker's observation (?) of echeneids consuming the hosts' faeces as a major dietary item.

Two recent papers suggest that the principal fare of echeneids may be entirely different from the foods suggested above. Szidat and Nani (*Rev. Inst. Invest. Mus. argent. Cienc. nat. 2(6):413*, 1951) observed the ectoparasitic caligid copepods *Achteinus* and *Pandarus* in the stomach of *R. remora*, and Maul (*Bol. Mus. Funchal 9:14*, 1956) found both caligid copepods and oxycephalid amphipods in this species. In addition, Maul discovered the planktonic heteropod *Atlanta* in the digestive tract of *Remoropsis brachypterus*. These authors postulate that echeneids and their hosts are symbionts, with the echeneid's function being parasite removal and consumption. Similar arrangements exist in birds which clean the hides and mouths of large reptiles and pachyderms, and also between wrasses of the genus *Labroides* and many other fish (Randall, *Pacific Sci. 12(4):327–347*, 1958). Neith Szidat and Nani nor Maul had adequate spec mens to depict the extent of parasite-feeding the Echeneidae, and the present paper was pr pared to illustrate the dietary trends apparent several genera and species. The specimens studie are presently in the collections of the U. S. Fi and Wildlife Service, Honolulu.

Material examined.—Identification of ech neids was made with the aid of the keys Maul (1956) and Schultz (*U. S. Nat. Mus. Bu 180:256*, 1943), with the following species bei present: *Rhombochirus osteochir* (Cuvier), *R mora remora* (Linnaeus), *Phtheirichthys lineat* (Menzies), *Remoropsis pallidus* (Schlegel), a *Remoropsis brachypterus* (Lowe). In addition meristic and morphometric characters, iden cation was also based upon the stained later line scales, as illustrated by Maul. Some di culty was experienced in distinguishing t species of *Remoropsis*, for in addition to spe mens with the respective color patterns a scales of *pallidus* and *brachypterus*, there we others with *pallidus* coloration but *brachypter* squamation. Scales were considered the mo reliable criterion in such cases, and these spe mens were labeled *brachypterus*. Szidat a Nani (1951) were followed in synonymizi *Phtheirichthys multiradiatus* Schultz with *lineatus* (Menzies). A summary of the data companying the specimens is presented in Ta 1.

Viscera.—The digestive tracts were remov while the fish were soaking in water preparat to transfer from formalin to alcohol. In no c were there evident any signs of improper pres vation.

Two types of internal anatomy were countered among the five species examined. the first, typified by *Rhombochirus, Remo* and *Phtheirichthys*, the digestive tract consis of a short esophagus, a muscular J- or Y-sha stomach, 4–7 large pyloric caeca, and a lo coiled intestine divided into anterior and terior portions by a valvular fold. Both regi of the intestine were densely papillate inte ally in all species, but the intestinal len varied from 130 percent of the standard len in *Rhombochirus* to 40–60 percent of the sta ard length in *Remora* and *Phtheirichthys*. smallest specimens of the latter genera had po differentiated viscera, the tract often appea as a simple straight tube, which was intern papillate, from mouth to anus. No dietary

TABLE 1

ECHENEID FISHES EXAMINED FOR FOOD

Species	Date	Latitude	Longitude	Sex	Standard length (mm.)	Host
mbochirus	7/20/50	05°42′N	171°54′W	F	161	*Makaira audax*
teochir	?	North	Pacific Ocean	F	218	?
	8/30/56	09°32′S	136°55′W	M	240	*Makaira ampla*
	8/30/56	09°32′S	136°55′W	F	282	*Makaira ampla*
ora remora	8/30/56	09°32′S	136°55 W	?	52	Attached to longline buoy
	2/10/56	21°23′N	158°29′W	M	84	*Pterolamiops longimanus*
	2/10/56	21°23′N	158°29′W	?	108	*Pterolamiops longimanus*
	8/21/52	07°02′N	140°46′W	M	131	*Pterolamiops longimanus*
	9/3/56	10°25′S	139°40′W	F	134	*Pterolamiops longimanus*
	3/18/56	00°11′N	139°53′W	M	154	*Pterolamiops longimanus*
	8/7/57	36°45′N	124°34′W	F	235	*Prionace glauca*
heirichthys	8/27/56	12°16′S	133°20′W	?	44	Attached to longline bait (herring)
neatus	8/28/56	11°23′S	134°32′W	?	46	In stomach of *Neothunnus macropterus*
	8/26/56	13°26′S	132°16′W	?	54	Attached to longline buoy
	9/29/51	21°24′N	158°15′W	F	300	Dipnetted beneath night-light
oropsis pallidus	9/1/56	07°30′S	138°57′W	F	119	*Makaira audax*
	8/21/52	07°02′N	140°46′W	F	126	*Makaira ampla*
	8/28/52	01°00′N	140°22′W	M	130	*Istiompax marlina*
	8/19/56	02°42′S	131°42′W	M	139	*M. ampla* or *I. marlina*
	9/1/56	07°30′S	138°57′W	M	148	*Makaira audax*
	8/19/56	02°42′S	131°42′W	M	167	*M. ampla* or *I. marlina*
	4/4/55	01°49′N	157°38′W	F	179	*Istiompax marlina*
	4/4/55	01°49′N	157°38′W	F	184	*Istiompax marlina*
	9/1/56	07°30′S	138°57′W	F	186	*Makaira audax*
oropsis	8/19/56	02°42′S	131°42′W	?	53	*M. ampla* or *I. marlina*
rachypterus	9/1/56	07°30′S	138°57′W	F	81	*Makaira audax*
	8/19/56	02°42′S	131°42′W	F	107	*M. ampla* or *I. marlina*
	8/19/56	02°42′S	131°42′W	F	110	*M. ampla* or *I. marlina*
	8/30/56	09°32′S	136°55′W	F	119	*Makaira audax*
	4/15/54	01°58′N	155°16′W	M	136	*Istiompax marlina*
	8/19/56	02°42′S	131°42′W	F	167	*M. ampla* or *I. marlina*
	8/18/56	00°57′S	132°24′W	F	197	*Istiompax marlina*

ences were noted between small and large
mora or *Phtheirichthys.*

The second type of visceral anatomy occurred
Remoropsis, and resembled the juvenile con-
ion of the other genera. The stomach and py-
ic caeca were ill-defined or lacking so that the
gestive tract was a straight papillate tube as
own by Suyehiro (*Jap. Jour. Zool. 10(1):217,*
12). In this connection, we were unable to
d the liver-like caecal mass noted by Suyehiro.
loric caeca were either absent or, in the
gest specimens, occurred as a series of short
aginations arranged radially posterior to a
minutive stomach. Again no differences in food
bits were detectable between specimens with
d without caeca and stomachs.

Results of the food study.—Table 2 summarizes
e occurrence of food material in the digestive
cts of each species. At this time I should like
acknowledge my indebtedness to Mr. Everet
Jones, U. S. Fish and Wildlife Service, Honolulu, for identifying most of the invertebrate food organisms. The foods were grouped by categories suggestive of the following feeding methods: plankton feeding, preying upon ectoparasites and other attached organisms, and consumption of scraps. This classification is arbitrary in that it was not known whether certain crustaceans were attached or free-swimming, and also in that the source of the scraps could not be determined. Conceivably, scraps could represent remnants of the host's meal, portions of large prey captured by the echeneid itself, fragments of bait used to capture the host, table scraps from the fishing vessel, or undigested material from the host's faeces. Despite these vagaries the data fall into several patterns as discussed below.

All species except *R. brachypterus* consumed some food in the scrap category. In most cases individuals doing this were outnumbered by those taking other food, and scrap consumption

TABLE 2

ITEMS FOUND IN THE DIGESTIVE TRACTS OF ECHENEID FISHES. FIGURES REPRESENT NUMBER OF FISH CONSUMING THE ITEM

Food item	*R. osteochir*	*R. remora*	*P. lineatus*	*R. pallidus*	*R. brachypterus*
Planktonic organisms					
Amphipoda, hyperiids	—	3	1	1	2
Amphipoda, unidentified	—	—	1	—	1
Decapoda, *Lucifer* sp.	—	1	—	—	—
Decapoda, crab zoea	—	1	1	—	—
Decapoda, unidentified larvae	—	2	—	—	1
Copepoda (calanoid), *Candacia pachydactyla*	—	1	—	—	—
Copepoda (calanoid), *Candacia aethiopica*	—	1	1	—	—
Copepoda (calanoid), *Candacia* sp.	—	—	1	—	—
Copepoda (calanoid), *Scolecithrix* sp.	—	1	—	—	—
Copepoda (calanoid), unidentified	—	1	2	—	—
Copepoda (harpacticoid), *Sapphirina* sp.	—	1	—	—	—
Copepoda (harpacticoid), *Oncaea* sp.	—	—	1	—	—
Stomatopoda, larvae	—	1	1	—	—
Euphausiacea	—	2	1	—	—
Mysidacea	—	1	—	—	—
Ostracoda	—	—	1	—	—
Crustacea, unidentified fragments	—	1	—	—	—
Mollusca (heteropod), *Atlanta* sp.	—	—	—	—	1
Mollusca (pteropod), *Cavolinia tridentata*	—	—	—	—	1
Fish, *Ranzania* sp. juveniles	—	2	—	—	—
Fish, *Gnathanodon* sp. juveniles	—	1	—	—	—
Fish, unidentified larvae and juveniles	—	2	—	—	—
Fish, unidentified bones	—	—	1	—	—
Fish, unidentified scales	—	3	—	—	—
Parasitic or attached organisms					
Copepoda (caligoid), *Nesippus* sp.	—	—	—	—	1
Copepoda (caligoid), *Gloiopotes* sp.	—	—	—	2	—
Copepoda (caligoid), pandarid	—	—	—	1	—
Copepoda (caligoid), caligid	—	—	—	1	—
Fish, unidentified echeneid	—	—	—	—	1
Scraps					
Fish muscle or liver	1	—	—	2	—
Unidentified muscle	—	—	1	—	—
Squid skin (?)	—	—	—	1	—
Grapefruit fragments	—	1	—	—	—
Meat from galley	—	1	—	—	—
Empty	3	1	0	3	3
Total examined	4	7	4	9	8

is therefore probably opportunistic rather than a regular way of life. Little can be said of the incidence of scrap consumption in *Rhombochirus.*

Miscellaneous adaptations.—In addition to the differences in viscera and diet discussed above, two other aspects of echeneid biology were investigated. The first concerns the manner by

which the parasite-feeding species obtain the
prey, in brief, whether they are structural
modified for capturing the flattened, clingi
"sea-lice" upon which they feed. In all speci
examined, the lower jaw projects beyond t
upper so that its short canine and villiform tee
enter the snout profile (see Suyehiro 1942:21
A measure of the degree of prognathism w
obtained by dividing the distance between t
tips of the two jaws by the snout length. E
cluding specimens shorter than 100 mm. (whi
all had greatly projecting lower jaws) this ove
bite averages 28 percent for *Remoropsis pallidi*
25 percent for *Remoropsis brachypterus,*
percent for *Remora remora* and *Phtheirichth*
lineatus, and 12 percent for *Rhombochir*
osteochir. Not only does *Remoropsis* have fro
50–100 percent greater overbite than the oth
genera, but its teeth are also longer and cou
seemingly be brought to bear on the host's sk
while attached by the sucker. It is thus co
ceivable that these fish obtain their parasi
food while attached to the skin of the host.

Fish and invertebrate plankton constituted t
principal diet of *R. remora, P. lineatus,* and
a lesser extent, *R. brachypterus.* In several ca
individuals were found with the alimentary tr
crammed with one or two planktonic spec
indicating either selectivity in feeding or patc
distribution of plankters. As is shown in Tal
2, *R. brachypterus* also fed upon ectoparasit
and Szidat and Nani (1951) and Maul (19
found *R. remora* doing the same. These t
species may be transitional with respect to di
feeding upon plankton when it is abundant a
taking parasites at other times. No ectoparasi
were found in *P. lineatus,* but to this should
added the fact that none of the present spe
mens was attached to a living fish (Table
Of the two fish removed from longline buc
the *R. remora* had an empty digestive tr
whereas the *P. lineatus* had consumed a vari
of planktonic organisms as well as scraps. T
P. lineatus taken from a longline bait contai
a single hyperiid amphipod.

Remoropsis pallidus is apparently largely
pendent upon its hosts' ectoparasites as fo
and as noted above, it may also feed upon re
nants of its hosts' meals. Its lack of dark p
ment and its propensity for dwelling in
branchial cavities of marlin are undoubte
additional modifications towards a highly s
cialized existence. Perhaps echeneids tend
invade the bucco-pharyngeal regions of th
hosts because of a concentration of paras
there; a similar explanation has been offered
Szidat and Nani (1951) to account for ec
neids' temerity around the mouths of sha

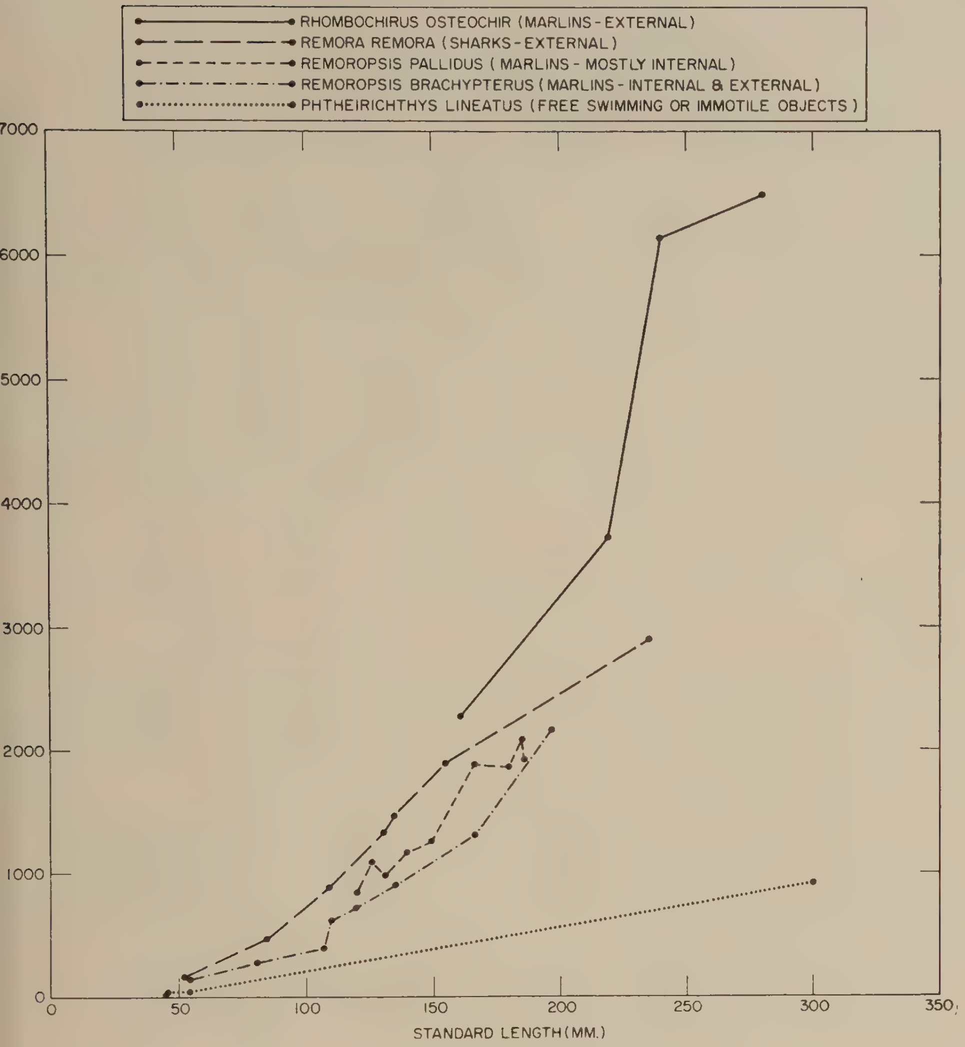

Fig. 1.—Echeneid disc size versus fish length and type of attachment to host.

is difficult to relate the difference in viscera th that in diet between the plankton- and rasite-feeding species.

It will be noted from Table 1 that some eche- ids were more or less host-specific, and the cond question deals with structural modifi- tions relating to this. The feature investigated s the sucking disc, with an attempt being ade to relate its area to the type of host or achment site. An approximation of the area the elliptical sucker was obtained by multi- ying its greatest length by its greatest width. eas obtained in this way have been plotted ainst fish length in Figure 1. It can be seen at the fish with the largest sucker, *Rhom- chirus,* attaches to the body skin of fast imming marlins, whereas the one with the smallest sucking disc, *Phtheirichthys,* is free-swimming or attached to immotile objects (it is also known from barracuda and sea bass—Schultz, 1943; Smith, 1950). Species intermediate in sucker-size attach to relatively slow-swimming sharks or take refuge beneath the opercula of marlins. Presumably water flow and turbulence are less in the branchial cavity than on the outside of these hosts.

From the above discussion it is apparent that echeneids occupy at least three ecological niches. They are predators on zooplankton and the smaller nekton, commensals taking scraps from their host, and symbionts removing the host's parasites as food. These trends appear to have some systematic basis for they are reflected in morphology, host selectivity, and the attachment site. The five species considered constitute a natural series ranging from the least host-dependent species to the most. At the primitive end of the scale is *Phtheirichthys lineatus*, and at the specialized end, *Remoropsis pallidus*. *Rhombochirus osteochir*, *Remora remora* and *Remoropsis brachypterus* are intermediates, with the first showing specialization in its ability to adhere, and the other two in tending toward parasite consumption.—DONALD W. STRASBURG, *U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Honolulu, Hawaii.*

4. Underwater Observations on the Behavior of Hawaiian Tuna

'he oceanic skipjack or aku (*Katsuwonus pelamis*)
ubject to a considerable fishery in Hawaii, Japan,
l the continental United States. Because this tuna
aught by chumming with live bait, and because
t is delicate and in short supply, the yield and
fit of the fishery are not as great as warranted
world demands. The Pacific Oceanic Fishery In-
tigations is attempting to increase the efficiency,
l hence the yield and profit, of live-bait fishing
studying skipjack behavior as it is related to
eral fishing variables.

'his study has been conducted from the research
sel "Charles H. Gilbert," which is equipped with
underwater observation chamber. Through this
mber movies were taken of skipjack behavior
ler normal and experimental fishing conditions. As
upplement to the movies, comments of underwater
l surface observers were recorded, along with
orded bell tones denoting catch rate. The ob-
vation chamber had three months of use during
58, a poor year for the Hawaiian fishery, during
ich observational techniques were developed while
periments were conducted. The experimental re-
ts, although encouraging, are only tentative.

Several experiments involved the effects of varia-
ns in chumming on skipjack behavior. When live
l dead nehu (*Stolephorus purpureus*) were chum-
d alternately, the use of dead bait resulted in
pjack decreasing their swimming speed and num-
of surface dashes, and also in falling so far
ern that fishing ceased. When the rate of chum-
ng was doubled, more nehu accumulated than
ıld be eaten by a small tuna school, again causing
the tuna to fall behind. This did not apply to large schools, for these consumed the bait as rapidly as it was thrown. With the chumming rate halved, the tuna slowed their swimming and tended to scatter, no doubt as a result of an insufficient feeding stimulus. When water sprays were turned on and off at intervals, the "off" condition resulted in speed-slackening, reduction in the number of surface dashes, and deeper swimming, again reflecting inadequate feeding stimulation. Experiments in which nehu were replaced by threadfin shad (*Dorosoma petenensis*) showed that a too-conspicuous or too-active bait also resulted in a reduced catch.

Four other experiments dealt with rather extrinsic fishing variables. Noise produced by hammering on the ship's hull had no effects on behavior, nor did blood sprayed in the water or allowed to drain from the deck. Skipjack skin extracts thought to contain fright-producing purines or pterines similarly produced no visible response. When red food coloring was sprayed into the sea in dense concentrations, skipjack avoided any deeply stained masses of water, suggesting that perhaps they can be corralled by walls of sufficiently dark dye.

As more is learned about bait-skipjack interactions it becomes easier to select better bait species and lures and to modify existing fishing practices. The results of such tests as the dye experiments may lead to entirely new fishing methods.

DONALD W. STRASBURG
Pacific Oceanic Fishery
Investigations
Honolulu, Hawaii

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ction 12 : Attraction of Fish.

SUMMARY OF EXPERIMENTS ON THE RESPONSE OF TUNA TO STIMULI

by

ALBERT L. TESTER*

Director, Pacific Oceanic Fishery Investigations, Honolulu, Hawaii, U-S.A.

tract

The aim of the experiments described in this paper was to obtain information which might lead to improved methods of tuna fishing, especially in finding a substitute for baitfish. In a series of tank experiments, it was found that yellowfin and little tunny responded to te light of moderate intensity but not to a weak light. Their reactions to chemical stimuli were also observed and a positive response was ained by using clear aqueous or alcohol extracts of tuna flesh. They were repelled, however, by copper acetate—the shark repellent. possibility of electrofishing for surface tuna was investigated and since it was demonstrated that electrotaxis could be induced in tuna an electric field of known characteristics, the problem becomes one of electrical engineering rather than of biology.

Résumé des expériences relatives à la réaction du thon aux stimuli

umé

Les expériences décrites dans cet article avaient pour but de recueillir des renseignements susceptibles de conduire à l'amélioration méthodes de pêche au thon, et plus particulièrement de trouver le moyen de remplacer l'appât vivant. An cours d'une série d'essais en sin, on a observé que les thons à nageoires jaunes et les "little tunny" (*Euthynnus yaito*) réagissaient à une lumière blanche d'intensité dérée mais non à une lumière faible. On a également observé leur comportement aux stimuli chimiques et l'on a obtenu une réaction itive par l'emploi d'extraits aqueux ou alcooliques de chair de thon. Toutefois, l'acétate de cuivre, utilisé pour écarter les requins, les a éloignés. possibilité de pêcher les thons de surface à l'électricité a été étudiée. et comme il a été démontré que l'on pouvait provoquer l'électrotaxie z le thon au moyen d'un champ électrique de caractéristiques connues, le problème relève plus de la technique de l'électricité que de la logie.

Resumen de los experimentos sobre la reacción del atún a los estímulos

tracto

Los experimentos descritos en este trabajo tuvieron por objeto reunir información para encontrar métodos mejorados de pesca de atún y, ecialmente, un sustitutivó del cebo vivo. En una serie de experimentos en estanques se encontró que el atún de aleta amarilla y el atunito ccionaban bien a la luz blanca de intensidad moderada pero no así a una débil. Ademàs se observó el efecto de las substancias químicas rándose una reacción al usar extractos acuosos o alcohólicos transparentes de carne de atún. Sin embargo los peces se alejaron al utilizar tato de cobre que se utiliza para repeler a los tiburones. También se investigó la posibilidad de emplear la electricidad para la captura los peces que nadan en la superficie, demostrándose que es posible producir la electrotaxia en el atún mediante un campo eléctrico de acterísticas conocidas, pero este problema cae más bien dentro del terreno de la ingeniería eléctrica que de la biología.

DURING the period 1951 and 1956, several staff members of the University of Hawaii conducted experiments, under contract with the Pacific ceanic Fishery Investigations (POFI) of the U.S. Fish d Wildlife Service, on the response of tuna to various pes of stimuli. The writer was leader of several of ese projects prior to joining the Service in 1955. is is a brief summary of the work to date.

The primary objective of the study was to obtain formation which might suggest new or improved ethods of tuna fishing. Efforts were directed particurly at devising a substitute for baitfish, the scarcity d high mortality of which limits the catch of surface na in Hawaii and prevents the expansion of the liveit fishery to potentially productive offshore areas.

STABLISHING TUNA IN CAPTIVITY

ethods of fishing, transporting and establishing tuna captivity are described by Tester[6]. Several species of na and tuna-like fish were caught by surface trolling off the windward shore of Oahu, including the skipjack (*Katsuwonus pelamis*), yellowfin (*Neothunnus macropterus*), and little tunny (*Euthynnus yaito*). Immediately after capture, fish were placed in the vessel's livewell ($67\frac{1}{2} \times 43 \times 32$ in.), which was supplied with running sea water (20 to 40 gallons/min.) but which, in addition, was aerated with finely-divided bubbles of oxygen from a pressure tank. They were then transported to ponds and tanks at the Hawaii Marine Laboratory (1 to 2 hours run), to which they were transferred by dipnet. Yellowfin (about 2 to 8 lb. in weight) and little tunny (about 1 to 6 lb. in weight) were successfully established in one of the large ponds (350 ft. long, 65 ft. wide and averaging about 6 ft. deep) which was flushed by tidal currents. Yellowfin and little tunny were also maintained in a concrete tank (35 ft. long, 11 ft. wide and 4 ft. deep) which was supplied with running salt water (about 25 gallons/min.). Skipjack were not successfully established;

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*Now Senior Professor of Zoology, University of Hawaii, Honolulu, Hawaii, U.S.A.

of numerous trials only one fish was transported alive from the fishing grounds to the laboratory and it died shortly after being released into the tank.

Except when on an experimental diet, the little tunny and yellowfin were fed cut-up fish, usually small tuna which died during our fishing operations or large tuna from POFI longline catches. The tunas generally started to feed within a week of introduction; otherwise they would die. When feeding fish were already present in the pond or tank, newly introduced fish would usually join the school and start to feed within one or two days.

The established (feeding) tuna survived for various lengths of time, ranging from but a few days to over 2 years. Some loss occurred from extraneous factors such as poaching or accidental stranding of the fish on dry land. Several of the fish developed partial or complete blindness and died either from starvation or injury. Others eventually became "sick", they moved slowly, listlessly and individually, ceasing to feed and eventually dying. Mortality occurred mostly during the fall and winter, and perhaps was associated with lowered temperature and salinity in the inshore environment.

Yellowfin, both in the live well of the boat and in the pond and tank, were relatively slow, leisurely swimmers. When two fish were present, they usually swam together. When several were present, they formed a loose school but often swam individually or in two's or three's. In contrast, the little tunny were rapid swimmers and usually formed a single, compact school. On occasions, when a large population (15 to 30 fish) was present in the pond, they formed two schools, but rarely more.

More detailed observations on the captive fish are included in the papers summarized below.

RESPONSE TO VISUAL STIMULI

During the summer of 1951, Hsiao[1] studied the response of two yellowfin and five little tunny to artificial light. The fish were confined in the concrete tank. The experiments were performed after dark, with the tank illuminated constantly with two 60 W. bulbs. He found that both yellowfin and little tunny were attracted to continuous white light over a range of moderate intensity (about 70 to 450 ft. candles). They were not attracted by a light of weaker intensity, and they were repelled by a light of stronger intensity. Both species were attracted to coloured lights of moderate intensity, but to no greater extent than to white light. Similar results were obtained with interrupted white light. There appeared to be no relationship between the strength of the response and the frequency of interruption of the light. Although the tuna approached an interrupted light of moderate intensity, they were repelled from the near vicinity at the instant the light flashed either on or off.

The above experiments suggest that tuna at sea might respond to continuous light of moderate intensity. To my knowledge, however, only tuna larvae and young have been caught by this method. If adults in their natural habitat were attracted by light, it seems likely that this already would have been discovered and utilized by tuna fishermen.

The response of a school of 12 captive little tunny to moving objects of various colours in the large pond was studied by Hsiao and Tester[2] during the summer of 1952. During daylight hours, a pair of lures was momentarily dipped into an "attraction" area once every 2 sec. by a remote control from a high tower. The lures consisted of 2 in. sections of rubber tubing of various colours. The number of "fish-seconds" in the area, the number of "passes" at the lures, and the time were recorded on a kymograph. Observations were made under control conditions, when lures were introduced, and when lures were used along with an extract of tuna flesh (see later) which was introduced into the pond from one end. Activity of the fish (number of school entrances, time spent in the area, and swimming speed) was greater when lures were used, as compared with control conditions, and was still greater when lures and extract were used together. Although, in general, the fish made more passes at white than at coloured lures (red, black, silver), the superiority of the white lures was slight. It may have been associated with greater visibility rather than colour preference. There is no assurance that white lures would be superior to coloured lures in the open ocean. Trolling data collected during 1951 and 1953 (Tester and Nakamura[9]) show no preference by the tuna with respect to either form or colour of the lure.

The above experiments deal with only one aspect of visual response, namely lure preference. Specific pond experiments on visual acuity were not undertaken. Casual observations indicated, however, that both yellowfin and little tunny could perceive objects such as stones or pieces of food which were thrown to them while the objects were still in the air. The fish would speed rapidly toward the point where such objects would hit the water. If the objects were not thrown so that the fish could see them in transit, the tuna could be attracted either by the splash made when the object hit the water, or perhaps by the object itself over a distance of about 50 ft.

In view of the conclusion (see later) that visual perception was of prime importance in attracting tuna to the stern of a fishing boat by the use of livebait, Matthews[3, studied the comparative morphology of tuna eyes, during 1955-56, using species of diverse habits and habitats (skipjack, yellowfin, and bigeye). No significant differences were observed. In addition, he conducted experiments to determine the focal length of the lens and other optical properties of the excised eyes of freshly-killed tuna immersed in a long salt trough, viewing a light source through a "window" in the chorion of the vitreous chamber, but with confusing results (unpublished). Contract work in 1956-57 was devoted to a study of the comparative histology of the retina in skipjack, yellowfin, bigeye, and albacore including observations on the frequency and arrangement of the rod-cone mosaics. Preliminary results[3, indicate a relatively large number of rods in the retina of the albacore, suggesting relatively greater adaptation to dim light than with the other three species.

RESPONSE TO AUDITORY STIMULI

Miyake[4] conducted experiments with captive yellowfin and little tunny during 1951-52 to discover (1) if tuna produced any sound and (2) if they could be attracted or repelled by sounds of various frequencies. Using a listening frequency ranging from about 0·1 to 70 kc., he was able to identify low frequency sounds produced by the sudden movement of the tail of the yellowfin in the tank. This might have some significance with respect to the mechanism of school formation. No sounds produced by tuna were detected at listening frequencies in the moderate, high, or supersonic range. In attempting to attract or repel tuna by continuous sound stimulation in the pond, sounds were emitted at many frequencies from 0·1 to 70 kc. Although the results were inconclusive, there were indications that yellowfin might be attracted by complex sounds of low frequency.

RESPONSE TO CHEMICAL STIMULI

Van Weel[12] studied chemoreception in both yellowfin and little tunny in the concrete tank during 1951. He found that both fish had a well-developed sense of smell or taste whereby they were attracted to certain food substances. They were strongly attracted to clear, colourless extracts of tuna flesh. Moreover, it was found that the attractant was contained in the *protein* rather than in the *fat* fraction of the clear extract. In general, the response of the little tunny was more pronounced than that of the yellowfin. On the other hand, there was no positive response of either species to *conditioned* water in which baitfish had been living, nor to extracts of either baitfish or squid. Copper acetate, a shark repellent, was also repellent to tuna, although its effect was not as pronounced as on fish of other species which were also present in the tank.

The above study was continued in 1952-53 by Tester, Van Weel, and Naughton[10]. In the tank, improvements were made in the techniques of observation, introduction of test material, and measurement of the response. Testing was hampered by accumulation of test materials because of the small volume of water in the tank and its slow replacement. This problem was reduced by conducting tests on tuna established in the large pond, introducing test material through a continuous stream of water supplied at one end of the pond by a pump, and observing the response of the fish from a 20 ft. tower, which overlooked an "attraction" area extending from about 40 to about 80 ft. below the outlet. Pond testing was hampered by such factors as poor visibility due to weather, power failure, and erratic behaviour of the fish.

The results confirmed Van Weel's[12] observations that a positive response was obtained from clear, aqueous or alcohol extracts of tuna flesh. This took the form of a feeding reaction and included one or more of the following components: speeding or acceleration of the swimming rate, a return to the area of stimulation, surfacing, fanning-out and eventually a breakdown of school formation, circling, splashing, and biting at incidental objects on the surface of the water. It was postulated that an attractant was present in the flesh, viscera and blood of several species of tuna and certain other fish. Successful methods of concentration and preservation of this substance were achieved in preparation for large-scale sea-testing. Considerable time was devoted to its fractionation, purification, and identification.

In addition some 40 chemical compounds were tested, including amino acids, vitamins, aromatics, proteins, etc. With some of these there seemed to be a sensing of the dissolved or suspended materials but in no case did the response include all the typical components of a feeding reaction induced by fish extract.

The conditioning of the tuna was discussed with respect to their response to fish extract. Obviously they had become conditioned to feeding on inert, dead rather than motile, living food for they had little interest in schools of small baitfish which at times were present in the pond in fair abundance and which would leisurely withdraw as the tuna approached. Obviously, also, they had become conditioned to being fed for they would mill close to an observer on his approach to the pond. It was concluded that the response of the tuna was not directly conditioned by the kind of food, i.e. the species of fish used as food. However, there was the possibility that the tuna formed an association between feeding and the smell or taste of the dead food, which was cut up or otherwise macerated and which might exude juices of similar composition. If so, the response would not necessarily be obtained from wild fish at sea.

Tester, Yuen and Takata[11] reported on further experiments with little tunny in the pond and with skipjack schools at sea. Pond experiments were improved by introducing test substances into a continuous stream of water which flowed directly into the attraction area at the foot of the observation tower. Continued screening of some 75 known compounds indicated a mere "sensing" of strong smelling materials. A carefully designed experiment involving feeding the fish at successive weekly intervals with cut-up squid, skipjack, and shrimp and testing their response to extracts of these same substances was conducted. A response to all three extracts was obtained regardless of the food being fed, but the response to a particular extract was slightly greater when the substance from which it was prepared was being used as food. This experiment tended to confirm the suspicion voiced earlier that the fish were conditioned to the smell of juices exuded from the food which presumably contained common or similar substances which stimulated the feeding response. It was hoped that, even so, tuna in their natural environment would respond to the extract, which might contain a substance exuded by living, injured, or uninjured prey to which "wild" fish were naturally conditioned. This hope was not realized.

Large quantities of extracts of skipjack, yellowfin, and anchovy were prepared during the winter, spring, and summer of 1953, tested on the captive little tunny and presented to schools of skipjack at sea. In a few instances the schools consisted mostly of skipjack but included yellowfin, little tunny, or frigate mackerel. In some tests the concentrated liquid extract was sprayed on the surface or pumped in a stream in the path of the schools. In others, it was presented to schools which had been *chummed** to the stern of the vessel by livebait (*Stolephorus purpureus*). The results were either negative or inconclusive. Unchummed schools could not be stopped by an arc or circle of extract. Chummed schools could not be held at the stern even when the extract was bucketed overboard. In a few tests, on releasing a large quantity of the extract after the school had been chummed to the stern and chumming was stopped, a few fish were seen jumping in or passing through the material. It was uncertain whether they were responding to the extract or chasing stray baitfish. The apparently negative results discouraged any further testing of extracts except in conjunction with lures as reported below.

**Chum*—live or chopped fish used as a lure.

RESPONSE TO EDIBLE AND INEDIBLE LURES

Tester, Yuen, and Takata[11] describe pond tests with edible lures, and sea trials with both edible and inedible lures. The pond tests showed that little tunny would eat edible preparations such as gelatin capsules, pieces of macaroni, and strips of agar gelatin, and that these were more avidly consumed it they were made chemically attractive, or palatable, with concentrated extracts of skipjack or anchovy. In some cases, also, the feeding response seemed to be greater if the lures were made more visually attractive, i.e., silvery in colour. The fish showed a distinct preference for the agar preparations.

Again, the results of sea tests of edible lures were negative. However, they were conducted during the autumn when skipjack schools were scarce and erratic in their behaviour. Several of the schools which failed to respond to our most promising preparation (agar strips impregnated with concentrated extract and with aluminum powder) also failed to respond to livebait.

Several types of inedible lures were tested at sea. These were used as chum both alone and along with liquid extract after the fish had been initially chummed to the stern of the ship with baitfish. There was a momentary response to shiny objects such as strips of tin (several of which were eaten), to silvery objects such as squares of aluminum foil, and to effervescing objects such as calcium carbide pellets. Similarly there was a momentary response to dead baitfish. The addition of extract had no apparent effect. The results indicated that the sense of vision plays a much greater role in feeding than the sense of smell. However, neither the visual lures nor a "drag-lure array" (designed to simulate a school of baitfish) towed behind the vessel, was successful in holding the fish at the stern.

On the hypothesis that motion was an essential component in visual attraction, attempts were made (unpublished) to devise an expendable, self-propelled motile lure which would simulate baitfish movement, and which would be made both visually and chemically attractive. Many types of "motors" (mostly generating air or gas) were devised, but none was satisfactory. A compressed-air "machine gun" was designed to project and at the same time activate compressed air cartridges. Following an unsuccessful sea trial, hampered by imperfections in the machine and poor behaviour of the released cartridges, this idea was abandoned.

RESPONSE TO ELECTRICAL STIMULI

Before conducting experiments on the response of tuna to electrical stimuli, it was considered best to obtain pertinent basic data on a more readily available marine species which could be easily kept in captivity. During 1951, Tester[7] studied the response of aholehole (*Kuhlia sandvicensis*) to interrupted direct current using a D.C. generator and various types of mechanical interrupters In a small salt water tank (12×2×1 ft.) the fish were forced to swim to the positive electrode when subjected to suitable combinations of current and frequency of interruption. The results indicated that, at a frequency of 15 cycles a progressive saving of power could be obtained by reducing the "current-on" fraction of a cycle from about 0·7 to 0·1. Power conservation, of course, is an important consideration in the practicality of marine electrofishing.

The above results were confirmed and extended by Miyake and Steiger[5] in further experiments with aholehole during 1954 and 1955, using storage batteries as the source of power. They concluded that the optimum frequency for electrotaxis was 10 cycles and that the minimum peak current for satisfactory response (12 amp) was associated with an "on-fraction" of 0·06 to 0·08. Total peak current requirements decreased with increase in length of the fish extrapolating the above results, they concluded that a current of 130 amp. at a potential of 60 V. would be required to induce electrotaxis in a fish the size of a small tuna (30 cm.) using plane 11×4 ft. electrodes spaced a distance of 33 ft. This was best achieved by condenser discharge. Accordingly an apparatus was constructed for experiments with tuna and other large fish in the concrete tank. It consisted of a bank of capacitors (55,000 mfd.) charged by any number up to 10 pairs of automobile storage batteries arranged in series parallel. The charging and discharging of the capacitors was controlled by a variable speed mechanical contactor.

With electrodes spaced at 33 ft. perfect electrotaxic response was obtained with a jack (*Carynx sp.*), using 60 V. (2 banks of 10 batteries) at 10 cycles. However, with little tunny and yellowfin the results were either inconclusive or negative. By spacing the electrodes a distance of 16 ft., thus increasing the electric field, an excellent electrotaxic response was repeatedly obtained with yellowfin tuna (about 50 cm. in length). The results showed that power requirements decreased (10 to 6 pairs of batteries) as the frequency increased to 20 cycles, the limit of the apparatus. Theoretical calculations indicated that 23 times as much power would be dissipated in the open sea as in the closed tank and that a correspondingly higher power output would be required to effect electrotaxis with the same electrode spacing and frequencies

In the same report, Miyake and Steiger[5] presented theoretical studies of the potential, electric field, and current density for spherical electrodes submerged in a large body of water. They also investigated the theoretical relation ship between the head-to-tail potential and current density in a fish as determined by the relative conductivities of the fish and water.

Following the 1954-55 results, reported above, the possibilities of utilizing an amplidyne to generate a pulsed direct current of satisfactory strength, waveform, and frequency for inducing electrotaxis were investigated in the laboratory with promising results (unpublished). Unfortunately continuation of the contract work has not been possible because the contractors have assumed other responsibilities.

DISCUSSION

Despite the large amount of information which has been obtained on the response of both captive and wild tuna o stimuli of various kinds, little progress has been made oward attaining the main objective. This was to devise a method of catching surface tuna, which was independent of the use of livebait.

It was realised at the outset that our approach was largely "trial and error" and that the probability of success was small. It was also realized that results obtained on captive fish, conditioned to pond life, might not be capable of extrapolation to wild fish of the open sea. Nevertheless, the approach seemed worthwhile in providing leads which might be tested by sea trials.

The pond tests demonstrated that the active little tunny and the less active yellowfin both have a keen sense of smell (or taste), together with excellent vision both through water and, with a calm surface, through air. The sea tests indicated that the sense of smell plays little, if any, part in natural feeding, although this is still an open question (a) because of the difficulty in making observations on the response of fish at sea, and (b) because the materials tested may not have included those which might be associated with living prey. These studies might well be repeated or perhaps extended in view of our recent discovery of a natural laboratory, a spot or "concourse" in the lee of an island where skipjack are always present and where their behaviour and response may be readily observed by underwater viewing devices which are presently being perfected.

Sea tests further indicated that vision played an important, and perhaps a dominating part in natural feeding and that motility of a lure, whether living or dead, whether edible or inedible, was an important attribute. These observations, also, can be repeated and extended at the skipjack concourse.

Although most of our pond observations were made on little tunny and, to a lesser extent, on yellowfin, our sea tests were conducted mostly on schools of skipjack. This again leaves an element of uncertainty in drawing conclusions regarding the negative results of sea tests.

The response of tuna to auditory stimuli was not adequately investigated; this work was abandoned in favour of the more promising fields of chemical and electrical stimulation.

The possibility of electrofishing for surface tuna, either with or without the use of bait, remains a promising area of study. Now that it has been demonstrated that electrotaxis may be induced in tuna with an electric field of known characteristics, the problem is one of engineering rather than biology.

Future efforts to devise new or improved methods of tuna fishing will be enhanced by further studies of the behaviour of tuna and their response to factors of the environment. Behaviour studies are rapidly becoming one of the major areas of research of the Pacific Oceanic Fishery Investigations and will occupy more and more of our attention in the years to come.

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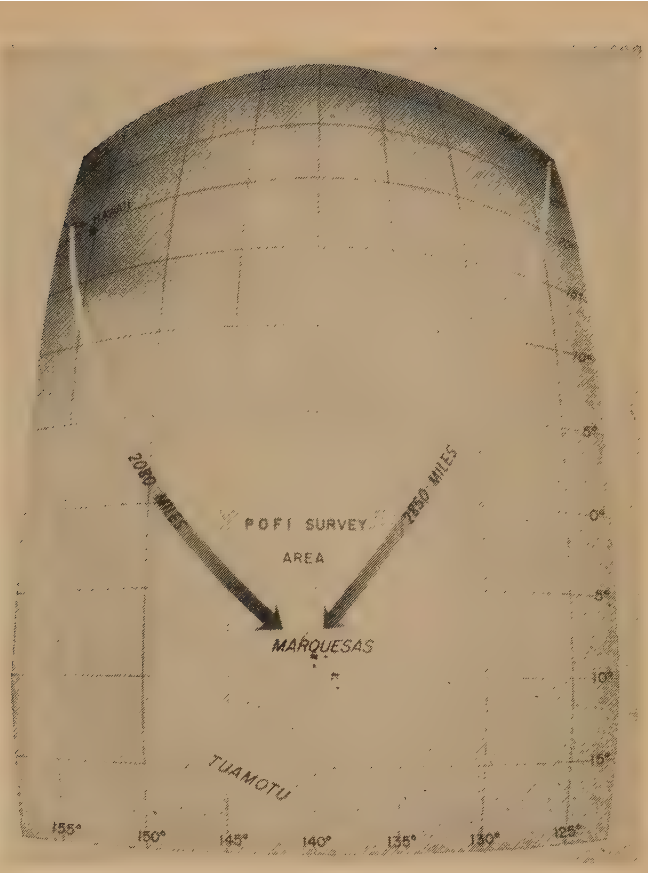
Tuna Season in the Marquesas

By
ROBERT C. WILSON
and
THOMAS S. AUSTIN

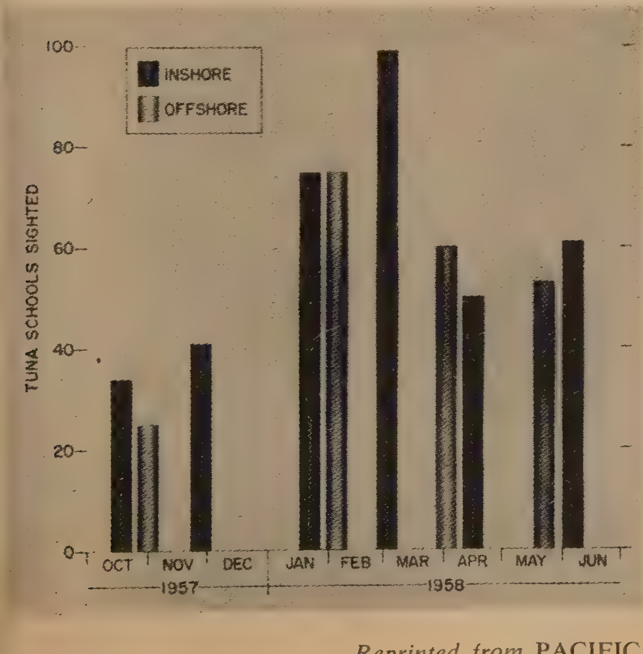
> *". . . The Marquesas! What strange visions of outlandish things does the very name spirit up! . . . As we draw near the land, I hailed with delight the appearance of innumerable sea fowl."*
> *Herman Melville, "Typee."*



• Many travelers have noted the myriads of sea birds about the Marquesas Islands, but it was not until the development of the tuna fisheries elsewhere that their possible economic significance was realized. Both the bird flocks and the schools of tuna have the same prey—the groups of small fish which provide their main food. More often than not, it is these flocks of birds which guide tuna fishermen to the schools.

Since mid-1956 the Pacific Oceanic Fishery Investigations (POFI) of the U. S. Fish and Wildlife Service has been engaged in a program, the primary purpose of which has been to describe the abundance of tuna schools in northeastern French Oceania, and more particularly the Marqueasas Islands. Most of the effort in this program has been focused on the Marquesas, because the group can be easily reached by the long-range segment of the American tuna clipper fleet, and the Marquesan sardine is available there as a possible supplementary supply of live bait.

The Marquesas Islands lie approximately 2,850 miles from San Diego. The group is governed by the French. They are high islands, and suitable areas for anchorage in the bays are numerous. The group lies in the belt of southeasterly trades, which are generally moderate, affording very few days when fishing cannot be carried on. Diesel fuel is not available there, but our vessels have obtained water at Taiohae, Nuku Hiva. Fresh fruit may be purchased from the Marquesans who are a Polynesian people.



Marquesan Survey results of the tuna schools scouting by POFI operations on inshore and offshore waters of the Marquesas, 2,850 miles from San Diego.

• Preliminary surveys of the area were conducted during August-September, 1956, (Marquesan winter) and January-March, 1957 (Marquesan summer). These cruises involved study of the oceanography of a broad area about the Marquesans, longline fishing for deep-swimming tunas, and surveys of the surface tuna schools in the Marquesas and Tuamotus. Results of these preliminary surveys revealed a striking difference in the abundance of tuna schools. They were about three times more abundant during the summer period (January - March, 1957) than during the winter period (August-September, 1956). Results also showed a higher concentration of inorganic phosphate and zooplankton, indices of the primary productivity of the area, during the winter.

In October, 1957, the surveys took a more definite turn, with the beginning of studies designed to determine the length of the season of greatest abundance of surface tuna schools in the Marquesas group and, to a limited extent, in the Tuamotu archipelago.

• There were two standardized types of surveys conducted, the "inshore" and the "offshore", which followed the tracks shown on Page 31. All of the

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tracks were run during daylight hours, and tuna "schools" were defined according to the following criteria:

1. Tuna school seen breaking the surface, birds may or may not be present.
2. A "working" (diving and feeding) flock of 50 or more birds seen, tuna breaking the surface may or may not be present.

Results from the inshore surveys conducted during October 1957-June 1958 (fig. 5) confirmed the greater abundance of surface tuna schools during the summer months, as follows:

Dates	Number of schools sighted
October 14-21, 1957	34
November 24-30, 1957	41
January 18-25, 1958	75
Feb. 27-March 5, 1958	99
April 11-19, 1958	50
June 1-10, 1958	61

In addition, four standardized offshore surveys were conducted, which further confirmed the seasonal nature of tuna distribution in the area:

Dates	Number of schools sighted
Oct. 24-Nov. 6, 1957	25
Jan. 28-Feb. 11, 1958	75
March 26-April 8, 1958	60
May 15-29, 1958	53

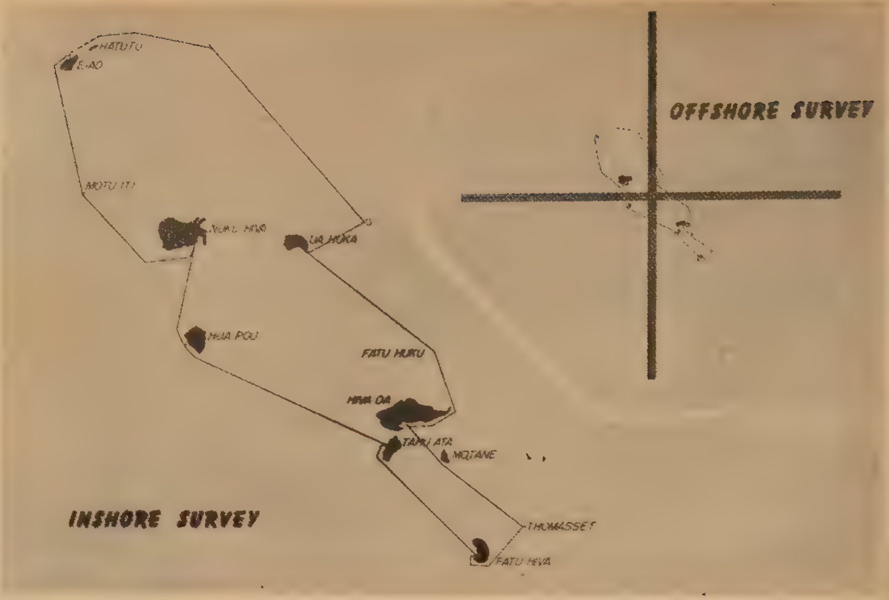
From these data it appears that within the period of the surveys, the abundance of tuna schools in the Marquesas area reached a peak during January-March, gradually tapering off thereafter.

Oceanic Skipjack tagged with the new type of dart tag finding favor with biologists as the best means of marking tuna yet devised.

About 80% of the identified schools were Skipjack, 15% were Yellowfin, and the remaining 5% were mixed Skipjack and Yellowfin. Virtually all of the small Yellowfin taken were from mixed schools. Of the schools of large 2- and 3-pole Yellowfin chummed, we were never successful in getting them to bite in any significant number. All of the Skipjack taken during the inshore surveys were under 10 pounds in weight, with most in the 4-6 pound weight group. However, Skipjack in the 18-22 pound weight class comprised 32% of the samples taken during the offshore surveys, with the remainder of a smaller size.

● The fishing success of POFI's research vessels is not necessarily comparable to that of a large tuna clipper because of restricted amounts of bait, fewer men in the racks, and the necessity to catch fish at a slow rate for tagging. The behavior of the schools can, in general, be described as wild and fast traveling.

The results of surveys of limited duration conducted in the northwest portion of the Tuamotu archipelago are perhaps more encouraging than those from the Marquesas. While the rate of sighting schools was lower, the schools were less wild, the fish bit better, and large Skipjack were relatively more numerous in the catch.



Where they Searched for tuna in the waters about the Marquesan Archipelago 8° degrees below the Equator on the 140th meridian.

In the Marquesas and Tuamotus, 4,584 Skipjack and 196 Yellowfin have been tagged and released, using the new POFI D-2 dart tag. To our knowledge, not one of these tagged fish has been recaptured. This is in striking contrast with the 9.7% recapture of Skipjack marked with the same type tag in the Hawaiian area. Thus it appears that the absence of returns from Marquesan fish is due to lack of fishing, and that this stock is presently unexploited to any great extent.

● The bait used during the fishing surveys was the Marquesan sardine. These fish, when used as chum, remain near the surface, form small schools, and attract and hold the tuna schools near the vessel. They do not withstand extreme crowding, either during transport to the vessel, or in the wells aboard. Once adjusted to life in the baitwells, they survive well. Most of the sardines were taken in shallow water of the bays, over sandy bottom.

But the supply of sardines has proven unreliable. During bait surveys made in January 1957, 1,200 scoops of bait were seen in Taiohae Bay, Nuku Hiva, and 500 scoops in Anaho Bay, Nuku Hiva. However, during the period January-June 1958, our vessels had great difficulty in scratching up the small quantities (100-200 scoops) of bait needed for survey work. So we cannot state with any certainty that a tuna clipper might procure sufficient supplementary bait in the area.

Examinations of the stomachs revealed a much higher percentage of fish in their diet than was the case in Hawaiian waters. Most of the fish species in the Marquesan Skipjack stomachs were those commonly thought to be associated with the proximity of land as has also proved true in Hawaii.

The conduct of POFI descriptive and exploratory programs has in general followed three phases: First an evaluation of the area and its environment, second a study of the fishery resource, and finally, an evaluation of the commercial possibilities. The first two phases are now completed. Currently under study are plans for evaluation of the commercial possibilities by encouraging a tuna clipper to conduct full-scale commercial fishing operations in the area during the January-March, 1959, season.

1959

Tagging of Skipjack in Hawaiian Waters

DANIEL T. YAMASHITA and KENNETH D. WALDRON[1]

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Tagging of Skipjack in Hawaiian Waters

DANIEL T. YAMASHITA and KENNETH D. WALDRON[1]

THE FISHING of the Hawaiian skipjack (*Katsuwonus pelamis*) though relatively small if compared with the major fisheries of the United States, is the most important commercial fishery in the Hawaiian Islands and the only American fishery exploiting mid-ocean stocks of skipjack. Annual landings average about 11,000,000 pounds with a value to the fishermen of about one and a half million dollars.

The Pacific Oceanic Fishery Investigations (POFI), of the U. S. Fish and Wildlife Service, is engaged in a skipjack tagging program which, it is hoped, will provide information that will increase the effectiveness of the local fishery. Tagging offers a direct means of increasing our knowledge of the growth rates, general migrations, and inter-island movement of the fish. In this report we will describe the type of tags used and the results of our initial studies during the years 1954 to 1956.

A major difficulty in early tuna tagging investigations (Rounsefell and Kask, 1945; Wilson, 1953) was the lack of a suitable tag. Alverson and Chenoweth (1951) contributed to the development of a better tag by their water tunnel experiment to determine the effect of flowing water on various tags attached to frozen albacore (*Germo alalunga*). Following this work, the California Department of Fish and Game developed a tubular plastic tag (Wilson, 1953) and used it extensively for tagging albacore, yellowfin (*Neothunnus macropterus*), and skipjack tuna (Ganssle and Clemens, 1953; Blunt, 1954); this tag is often called the type G or spaghetti tag.

Prior to announcement of the successful California tag, POFI experimented with several other types, both at sea and in ponds. These tests involved internal tags and external tags of the hook and streamer type. Experiments conducted in 1950 and 1952 were either inconclusive or unpromising, so the California tag (Fig. 1) was adopted for use in Hawaiian waters from 1954 to 1956.

APPLICATION OF THE TAGS

The type G tag was applied in the manner described by Wilson (1953), with certain modifications. Skipjack were caught by live-bait fishing methods as described by June (1951), with 3 or 4 men in the racks. A skipjack was hooked, swung up, caught by the fisherman, passed to a man designated as "holder," the tag was attached, and the fish was returned to the water. With an experienced crew a skipjack could be tagged and returned to the water in about 20 seconds.

Because it is difficult to handle skipjack without injuring them, various methods including canvas cradles, padded boxes, and electronarcosis were used in attempts to calm the fish. None of these was successful. Since it was deemed necessary to return skipjack to the water as rapidly as possible and since our efforts to quiet the fish were unsuccessful, no attempt was made to measure individual fish. Instead an estimate of the size of skipjack tagged was obtained by measuring fish which were caught and not tagged. Brock (1954) has shown that skipjack school by size, so it was believed that a reliable estimate of the size of tagged fish was obtained in this manner.

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[1] Fishery Research Biologists, Pacific Oceanic Fishery Investigations, Honolulu, Hawaii. Manuscript received March 12, 1958.

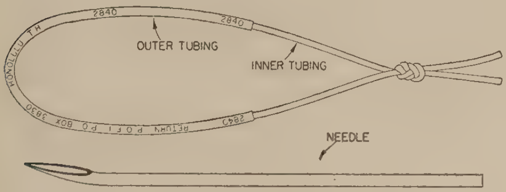

FIG. 1. California type G tag and tagging needle. Legend is on inner tubing only; serial numbers on inner and outer tubing.

Most of the skipjack tagged as described above sounded immediately upon release. On a few occasions they were seen to lead fish from the accompanying school away from the stern of the vessel. While some tagged fish left the school when released, there were indications that others remained in the same school from which they were caught. In one instance a fish released with a white type G tag was observed accompanying the vessel with part of the school for 4½ hours.

RELEASES

Between May, 1954, and July, 1956, 1,961 skipjack were tagged with the California type G tag and released in Hawaiian waters (Fig. 2).[2]

Most of the releases were within the area of the Hawaiian skipjack fishery; a few were released outside this area. This release pattern was followed in order to (1) establish the rate of recovery within the fishery, (2) study the movements of skipjack within the fishery, and (3) ascertain the direction from which skipjack approach Hawaiian waters.

It should be pointed out that the tagged fish were smaller than the usual size (18–22 pounds) composing the season's commercial landings. Eighty-five per cent were 10 pounds or smaller, 14 per cent between 11 and 20 pounds, and only 1 per cent larger than 21 pounds. The small percentage of releases in the larger size categories is due partly to the difficulty in handling these fish, and partly to the general scarcity of large fish when most of our tagging was done.

PUBLICITY PROGRAM

Publicity is an important part of most tagging programs, because one way to maximize the returns is to minimize the loss of tags recovered but not noticed by persons unaware of the program. We conducted personal interviews with skipjack fishermen on all islands and distributed posters to major fishing companies, fishing supply centers, and ports throughout the Hawaiian Islands. Fishermen were also informed of our tagging activities through radio broadcasts, transmitted by POFI vessels during their cruises in Hawaiian waters, and through informal letters. Also, wardens of the Hawaiian Division of Fish and Game stationed on the various islands were furnished photographs of tagged skipjack, together with standard recovery information forms. Because of the distinctive appearance of the tag, the publicity program, and the extensive handling of individual fish (when caught, during stowage and unloading of catch, and during butchering at the cannery), the possibility of loss of tags through nonrecognition of tagged fish was considered negligible.

Rewards for the return of tags were not part of the recovery program. Instead we purchased the tagged fish at a price slightly above the market value. A letter giving pertinent information was also sent to the person, or persons, involved in the recovery.

RECOVERIES

Of the 1,961 skipjack tagged and released, 9 were recovered by the commercial pole-and-line fishery and 3 from the stomachs of large longline-caught tunas between July, 1955, and February, 1956. The areas of release and recapture for these 12 skipjack are shown in Figure 3 and listed in Table 1. The low rate of recovery, 0.6 per cent, may be attributed in

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[2] In addition, 20 skipjack were tagged with white type G tags and released in the vicinity of the Line Islands, and 12 with blue type G tags northeast of Midway Island.

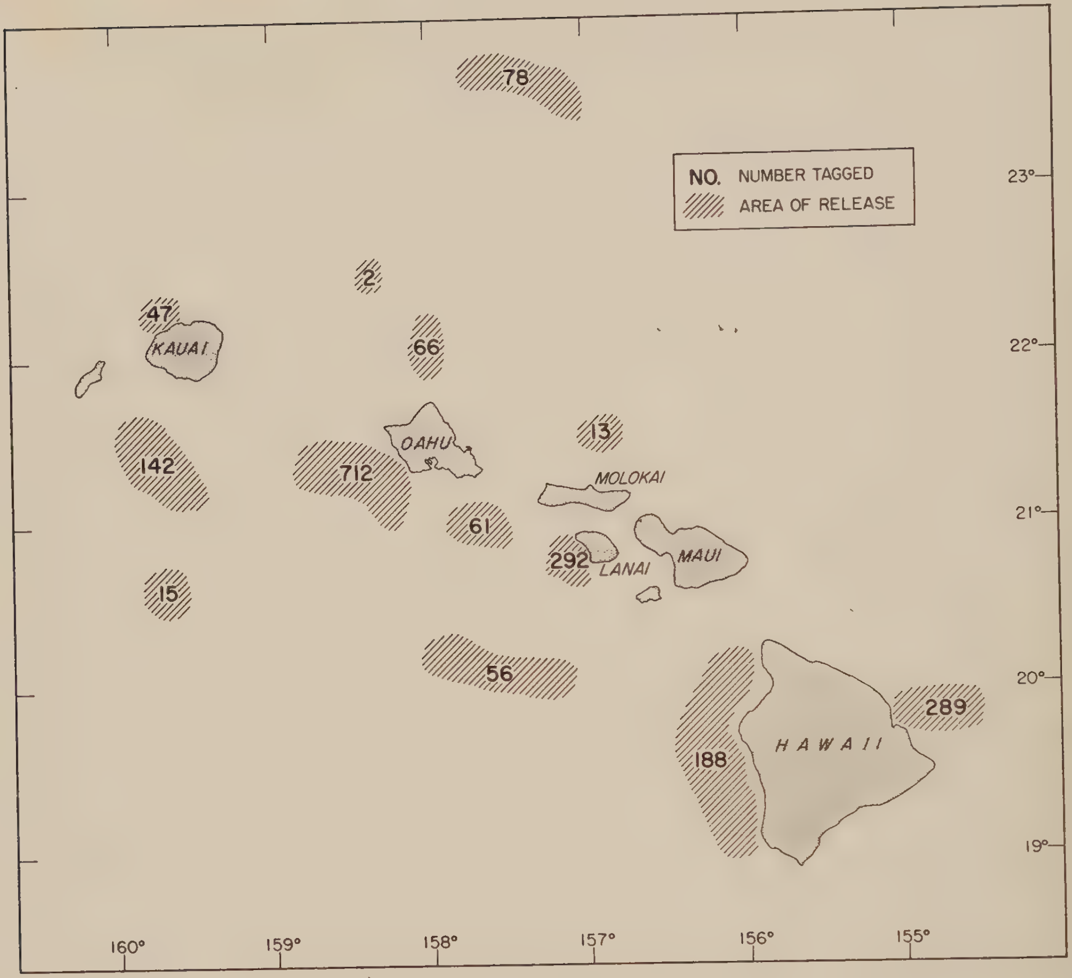
78
NO. NUMBER TAGGED
AREA OF RELEASE
23°
2
47
KAUAI
66
22°
OAHU
13
142
712
MOLOKAI
21°
61
292
LANAI
MAUI
15
56
20°
289
HAWAII
188
19°
160°
159°
158°
157°
156°
155°

FIG. 2. Skipjack releases in Hawaiian waters, May 1954–July 1956.

part to a combination of the following factors: (1) the initial tagging mortality resulting from handling in the tagging process may have been high; (2) mortality caused by predation of large tunas and spearfishes may have been excessive; and (3) certain groups of tagged skipjack may have moved out of the area covered by the fishery.

Condition of Tags and Fish: The condition of the tag and of the skipjack was noted for each of the 9 pole-and-line caught recoveries. One fish, recaptured after only 6 days at liberty, showed quick recuperation. The tag wound appeared raw and enlarged but there were no signs of infection. Another skipjack, retaken 12 days after tagging, had new skin forming around the edges of the tag wound.

Most of the recovered fish showed a slight chafing of the anterodorsal margin of the caudal fin, caused by the free ends of the tag striking the fin. This could be prevented by trimming the ends of the tag after the knot was tied.

One skipjack recaptured 252 days after release bore only the outer jacket portion of the tag. This protruded from the right side of the fish. The wound on the left side had

TABLE 1
POFI SKIPJACK RECOVERIES WITH WHITE CALIFORNIA TYPE G TAG

ORDER OF RECOVERY	WEIGHT RANGE OF SCHOOL AT RELEASE	DATE TAGGED	DATE RECOVERED	DAYS OUT	DISTANCE TRAVELED	WEIGHT AT RECOVERY	REMARKS
	Lbs.				Miles	Lbs.	
1	5–10	6/1/55	7/12/55	41	0	3–4	Recaptured from one school
2	6–8	6/8/55	7/12/55	34	0	3–4	
3	3–5	7/20/55	7/26/55	6	40	4	
4	5–8	7/18/55	7/30/55	12	0	6	
5	3–6	8/22/55	8/24/55	2	6	3½	Found in stomach of longline-caught 189-lb. yellowfin
6	3–5	7/20/55	8/28/55	39	17	4	
7	4	8/17/55	8/17–8/26/55	0–9	0(?)	–	Tag only found in stomach of longline-caught 190-lb. yellowfin
8	3–5	8/25/55	8/25–9/1/55	0–7	0	4	Found in stomach of longline-caught 209-lb. bigeye
9	4–5	8/8/55	8/29/55	21	14	3	Recaptured from same school
10	4–5	8/8/55	8/29/55	21	14	3	
11	4–5	8/8/55	10/29/55	82	9	4½	
12	5½–9½	5/25/55	2/1/56	252	30	14	

healed completely and was marked only by a black spot on the skin (Fig. 4). Adhesion between the flesh and the plastic held the tag in place.

Movement: All of the skipjack recovered were small (3 to 10 lbs.) when tagged. They showed surprisingly little movement, all of them being recaptured within 40 miles of the point of release (Fig. 3 and Table 1). There was no inter-island movement of tagged fish. The probability of recovery of tagged skipjack in offshore waters (beyond 50 miles from land) is low because very little fishing is done in this area. However, each of the main Hawaiian islands has fisheries within 20 miles of shore, so this lack of evidence of inter-island movement cannot be attributed to the distribution of fishing effort.

Two of 39 fish (Table 1, recoveries 9 and 10) released in one group were recaptured 3 weeks later from a single school, indicating that a school of skipjack retains its identity as a unit for some time. Recoveries 3 and 6 tagged on the same day and from the same school, may provide an example of the usefulness of this hypothesis. This school may have traveled 63 miles between July 20 and August 28, 1955; 40 miles to where No. 3 was retaken, and 23 miles back to where No. 6 was retaken. Similarly, the group in which recoveries 9, 10, and 11 were released may have traveled a minimum of 37 miles between August 8 and October 29, 1955. These are straight-line distances, and in all likelihood a much greater distance was covered during this period.

Growth: Information concerning the rate of growth of skipjack was gained from a tagged fish which weighed 14 pounds when recovered after 252 days (8.4 months) at liberty. Based on the average weight of fish (7 pounds) and the size range of fish (5.5 to 9.5 pounds) in the school at the time of release, a comparison may be made with the growth rates obtained by Brock (1954) in his length frequency studies. If this tagged fish was at the lower end of the size range (i.e., 5.5 pounds) when tagged, it grew at the rate of about 1.0 pound per month. This closely approximates Brock's estimate of 1.2 pounds

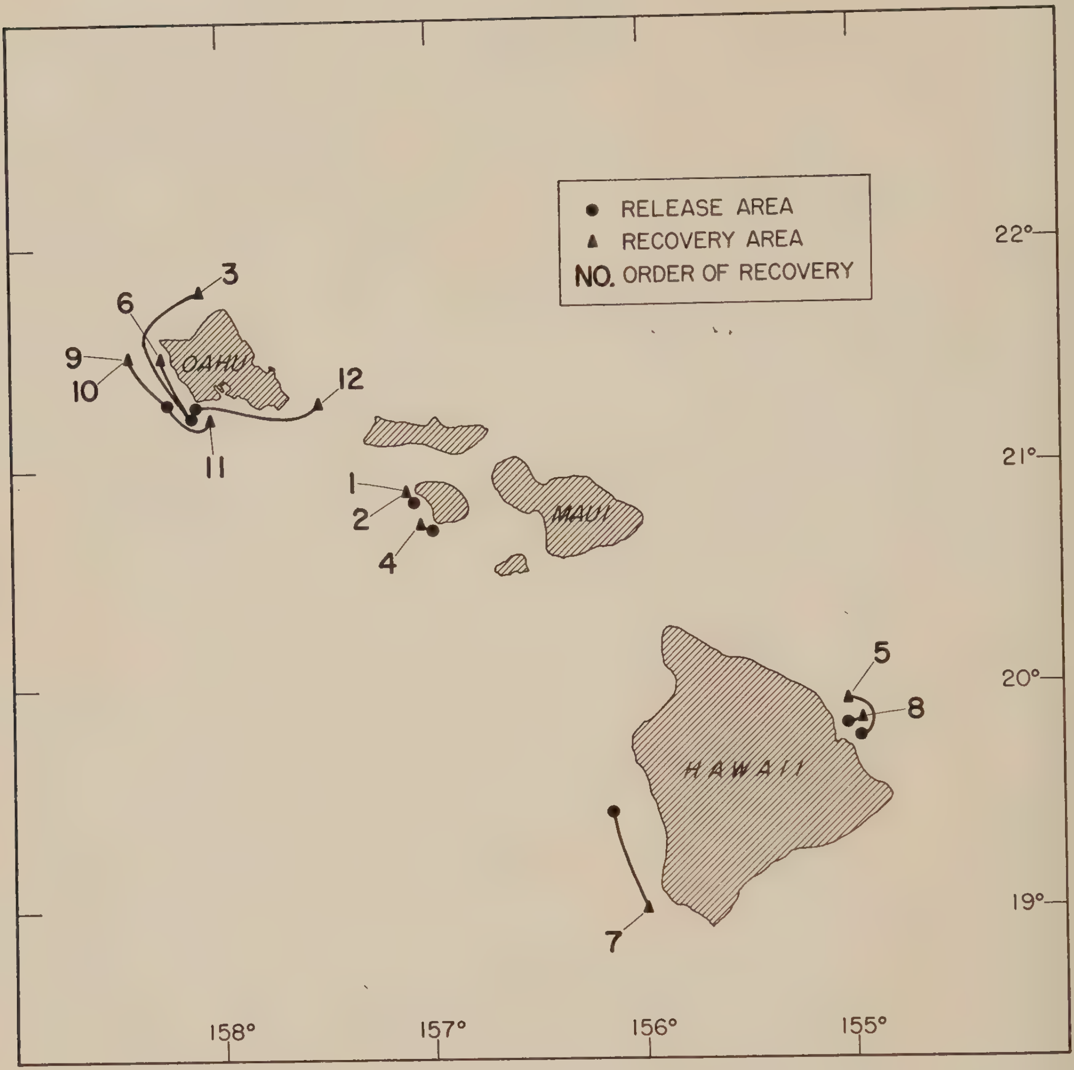

FIG. 3. Skipjack recoveries in Hawaiian waters, July 1955–February 1956.

per month for skipjack of this size (from his fig. 2). If the fish was of average size (i.e., 7 pounds) at the time of release, then a growth of 0.8 pound per month is indicated, which is slightly more than one-half the growth of 1.4 pounds per month shown by Brock. Finally, if the fish was at the upper limit of the size range (i.e., 9.5 pounds), it grew at the rate of 0.5 pound per month, or one-third the rate of growth of 1.5 pounds per month indicated by Brock.

Predation: There was evidence that some loss of tagged skipjack resulted from predation. Two tagged skipjack and one tag were recovered through incidental examination of stomachs of large tuna caught by longline near the island of Hawaii (recoveries 5, 7, 8 in Table 1). All three skipjack weighed about 4 pounds and were recovered within a few days of release. They were the only recoveries of skipjack released in that area.

In order to determine the incidence o skipjack, tagged or untagged, in the stomachs of larger fish, a sampling program at th

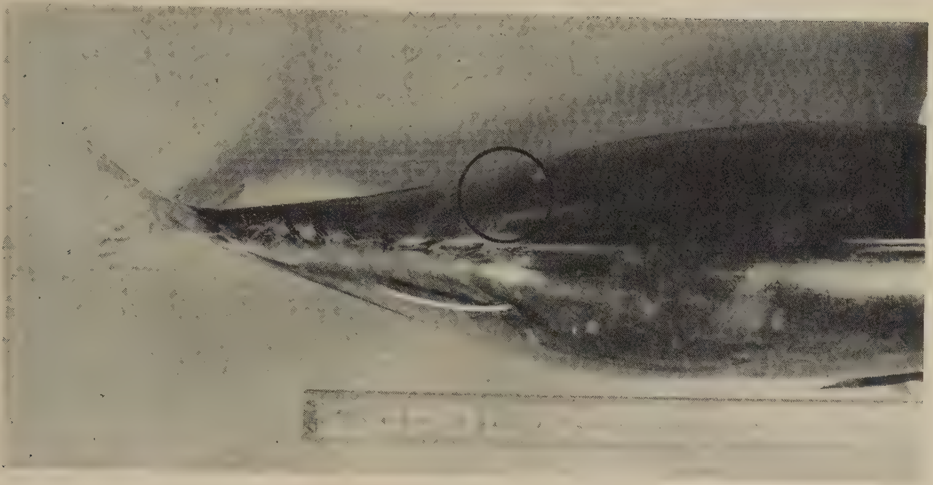

FIG. 4. Tagged skipjack recovered 252 days after release with only the jacket portion of the tag still in place. Dorsal view showing healed wound (dark area in circle) on the left side. Photograph by E. D. Stroup.

Honolulu auction markets was carried out etween October, 1955, and June, 1956. During this interval, which included periods when kipjack were being tagged and released vithin the fishery, stomachs were examined rom 538 bigeye (*Parathunnus sibi*), 103 yelowfin, 128 striped marlin (*Makaira audax*), nd 74 black marlin (*Makaira ampla*) taken n the Hawaiian longline fishery. Twentyight of these stomachs (3.3 per cent) conained a total of 30 skipjack, none of which vas tagged. Furthermore, only 9 of the 30 kipjack were as large as those being tagged, .e., 2 pounds or larger, and the rest were stimated to be 1 pound or less. Only one arge skipjack was taken from the stomach of tuna; the others were from black and striped narlins. Unfortunately, there are no comarable data concerning the number of unagged skipjack from stomachs at the time e three tagged fish were found, but on the asis of subsequent sampling it seems that here was a higher rate of predation on tagged han on untagged fish.

SUMMARY

A tagging project was inaugurated to study igrations and to supplement our knowledge of growth of skipjack in Hawaiian waters.

During the period 1954–1956, California type G tags were attached to 1,961 skipjack released in Hawaiian waters. The majority of these fish weighed less than 10 pounds.

Only 12 or 0.6 percent of these fish were later recovered. This low recovery rate may be attributed to tagging mortality, predation, and movement out of the fishery.

The longest interval between release and recovery, by pole-and-line fishing, was 252 days and the shortest interval was 6 days.

Net movement was limited to 40 miles or less and no inter-island travel was shown.

The tag wounds on recovered skipjack were enlarged but well healed after 12 days. When used on smaller fish, the free ends of the tag caused chafing of the anterodorsal margin of the caudal fin.

One skipjack weighing 14 pounds at recovery grew at an estimated rate of 0.8 pound per month over an 8½-month period.

Predation by large tunas and spearfishes may be greater on tagged than on untagged skipjack. This conclusion is based on the recovery of three tagged skipjack from the stomachs of large tuna.

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VARIABILITY OF SKIPJACK RESPONSE TO LIVE BAIT

BY HEENY S. H. YUEN

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From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 60

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*

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March 3, 1849

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ABSTRACT

Observations made from commercial skipjack live-bait fishing boats, operating from Honolulu, revealed that catch rates for each school of skipjack had a general pattern: the rates rose to a peak and then declined with elapsed fishing time. In this paper, peak catch rate and duration of fishing after the peak were selected as measures of biting response and were compared with data on location, the weather, time of day, and stomach contents. With a fork length of 60 cm. as the dividing line between small and large skipjack, the peak catch rates for small fish were higher than those for large fish, but this was attributed to the greater ease of catching small fish. The peak catch rate of large skipjack increased with the distance from land. The postpeak duration of fishing for large skipjack was found to be negatively correlated with volume of stomach contents and relative time since the last major feeding. Large skipjack feeding on fast-swimming fish seemed to show a better response to chum (live bait) than did those feeding on slow-swimming fish. Weather conditions did not seem to affect the peak catch rate or the postpeak duration. The relation of biting response to time of day was not obvious.

VARIABILITY OF SKIPJACK RESPONSE TO LIVE BAIT

By **Heeny S. H. Yuen**, ***Fishery Research Biologist***, **BUREAU OF COMMERCIAL FISHERIES**

Fishermen in the Hawaiian Islands chum live it to attract skipjack (*Katsuwonus pelamis*) to ship and to hold them there. The reaction skipjack to chumming may vary from no re- onse to feverish feeding activity which results a sizable catch. In reporting the results of e-bait fishing aboard research ships of the Pa- ic Oceanic Fishery Investigations[1] in Hawaiian aters, Royce and Otsu (1955) stated that fish ere caught from only 43 percent of the schools ummed. Time and bait expended on nonre- onding schools represent a considerable eco- mic loss to the fishermen, particularly because the short supply of bait.

If the efficiency of the fisherman is to be im- oved, the factors which contribute to the vari- ility of skipjack responses to chum should be certained. A prerequisite to this would be to easure the extent of variability of biting be- vior. It is the intent of this study to measure d determine the reasons for the variability of ipjack response to chum.

Perhaps the measure of variability of response ill have further application. For instance, it ay be used to evaluate the success of new bait ecies and artificial baits, or to compare the re- onse of skipjack in unexploited areas to that of resent commercially successful areas.

Factors influencing the biting behavior of skip- ck, as presented by past studies, may be classi- ed as environmental, physiological, and psycho- gical or perhaps psychophysiological. Among e environmental factors in the Japanese skip- ck fishery, Imamura (1949) mentioned water larity, current velocity, weather, abundance of atural food, and time of day. Transparency, lorinity, and temperature of the water are ad- anced by Uda (1940b) as affecting skipjack atches, but probably as migrational rather than esponse determinants. Uda (1940a) and Suyehiro (1938) also mentioned time of day as a factor. The latter also noted the effect of seasons and the proximity of land on biting behavior.

The first physiological factor that comes to mind when considering biting response is the state of hunger. Both Uda (1933) and Suyehiro (1938) investigated its effect; the former in terms of fullness of the stomach and the latter in terms of time since last feeding. That the state of gonad development may also be a factor is indicated by Brock (1954) who reported a dearth of ripe individuals despite extensive sampling of the Hawaiian skipjack fishery.

The factor that was considered as a psychological or psychophysiological one was the possible preference of the skipjack for certain species of prey or perhaps for prey with certain types of behavior. This possibility was conjectured because of Suyehiro's (1938) statement that skipjack feeding on pelagic forms responded to chum better than those feeding on inshore forms. The effect of school size, if any, would also fall in this category.

The size of the skipjack and the fishing effort measured by the number of hooks fished were also considered as possible factors.

Since the data were collected by investigators who were permitted aboard commercial vessels with the provision that they would not interfere with the fishing operations, not all of the possible factors mentioned could be measured. Unfortunately, the data not collected fell in the environmental category.

Operations on a skipjack sampan are not geared to accommodate observers, but the following captains and crews went out of their way to make us comfortable and to help us collect our materials: Yoshiichi Teramae and crew of the M/V *Neptune*, Tsuruichi Sarae and crew of the M/V *Orion* (1956), Richard Kinney and crew of the M/V *Orion* (1957), Noboru Tsue and crew of the M/V *Buccaneer*, Tom Fukunaga and crew of the M/V *Angel*, and Kuniyoshi Asari and crew of the M/V *Marlin*.

NOTE.—Approved for publication September 26, 1958.

[1] Redesignated Bureau of Fisheries Biological Laboratory, onolulu, effective January 1, 1959.

METHODS

COLLECTION OF DATA

Data were collected by observers who accompanied skipjack sampans throughout the 1956 and 1957 skipjack seasons, April through September, at about weekly intervals. Only the more successful and larger of the sampans were chosen because the probabilities of getting data would be enhanced and the larger deck permitted collection of materials with less interference to fishing operations.

A review of fishing operations described in greater detail by June (1951) follows: the boat leaves port early enough to be at a promising fishing area at daybreak. It is usually held on an arbitrary course while the scouts scan the ocean for birds that flock over fish schools. When a flock is sighted, the boat is steered to head it off. On reaching the head of the flock, the boat is slowed, water sprays are turned on, and chumming is started. The bait is dribbled out as evenly as possible until signs of surfacing fish are seen astern. When the fish begin to surface, the chummer intensifies the chumming until the fish are directly at the stern within reach of the hooks, at which time he reduces the rate of chumming to what he considers a minimum to keep the school at the boat. If the school moves away without responding, chumming is stopped and the boat accelerated to get into position for another attempt. As soon as the school has been successfully lured to the boat, the fishermen get into position at the stern and start fishing. The school is fished until the bait supply is exhausted or until the captain decides that the rate of catching is too slow to be worth while. The catch is stored as soon as fishing is stopped, and the boat then proceeds homeward or to look for more schools depending on the bait supply and hour of day.

The fishing of 92 skipjack schools was observed. Recording of data started with the sighting of a flock. The time of sighting was recorded to the nearest minute. During the approach a description of the weather was recorded. It included the height of the waves, an estimate of wind velocity and direction, the type of clouds and amount of sky covered, and light conditions. "Light" was described as bright sun, cloudy-bright, hazy, dull, and raining.

A running description of the activity of the flock was kept during the approach, and when the boat was close enough an estimate was made of the number in each flock and the species. The flocks were described as flying high, diving, scattering, regrouping, enlarging, etc. In the beginning, attempts were made to estimate the direction and velocity of the flocks but these were abandoned as being unreliable. As soon as contact with the school was made, its location was approximated.

The times of the following events were recorded to the nearest 5 seconds: (1) the beginning and end of each pass, (2) the first signs of fish surfacing in response to the chum, (3) the start of fishing, and (4) the landing of the first fish. During the few instances when the slowing of the boat and the start of chumming did not coincide, the latter was considered to be the start of the pass. The placement of hooks in the water signified the start of fishing.

As fish were caught, each was tallied on a counter. At the end of each minute (when the second hand pointed to 12) the reading was recorded with the time. If fishing did not start exactly on a minute, an error with a limit of plus or minus 30 seconds was introduced in the first minute. On earlier trips the catch was recorded at 2-minute intervals. Occasionally an individual fisherman left his post to change his fishing pole or to perform other duties such as helping the chummer, or to gaff fish. Each change in the number of men fishing and the time was noted, except when a man went to change his pole, a temporary absence.

The possibilities for error, especially when the fish were landed rapidly, were ever present with the observer watching the time, tallying the number of fish caught, accounting for the movements of the fishermen, and recording. Another method which decreased the amount of work during the hectic time of fishing and thereby reduced the possibilities of error was later used. This included the use of a movie camera with a single-frame trigger and a marine clock with white numerals against a black background. These were mounted facing each other (fig. 1). The shutter was released as each fish was caught, resulting in an exact record of the time of capture. The number of frames used corresponded to the number of fish

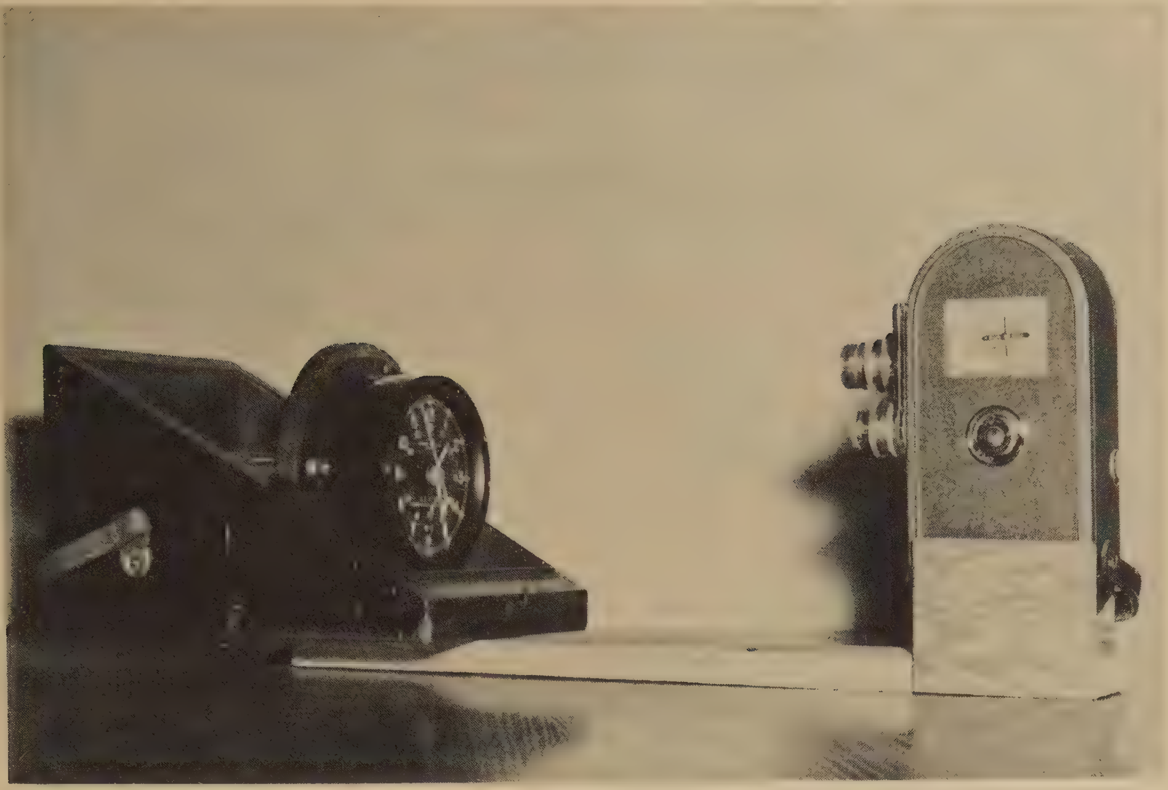


FIGURE 1.—Photograph of clock and camera setup.

caught. An additional hand on the clock was manipulated to point to the numeral corresponding to the number of men fishing at any time.

The precision of this system depended on the speed at which the single-frame trigger could be operated. The smallest possible interval of time between frames was 0.6 second. This means that when several fish were caught simultaneously, the record would indicate that they were caught 0.6 second apart.

At the cessation of fishing, the skipjack were randomly sampled. At first the sample size was 20, but this was later reduced to 10. The sample comprised the entire catch when the catch was less than the prescribed sample size.

The fork length of each fish in the sample was taken, then the stomach and a piece of the gonads were removed and placed in a muslin bag. The stomach was punctured while in the bag and the bag secured and placed in approximately 10-percent formalin. Five hundred and thirteen fish, representing 43 schools, were treated in this manner.

During the period between the 1956 and 1957 seasons, the personnel of the M/V *Buccaneer* collected 60 stomach samples from 6 schools. The data collected with the samples included: (1) the location of the school, (2) the time of fishing, (3) an estimate of the weight of the total catch from the school, (4) an estimate of the average weight of the fish, and (5) a statement of whether fish response was good, fair, or poor.

TREATMENT OF DATA

The rate at which the fish were caught, in terms of fish per hook-minute, was calculated for each minute of elapsed fishing time for the schools observed later in the study. For the schools observed earlier, the nature of the data did not permit the rates to be calculated for intervals of less than 2 minutes.

In the identification of the stomach contents the fish were placed in their families, mollusks in their suborders, and crustaceans in their orders. The individuals in each category were counted. The volume for each category was ascertained by water

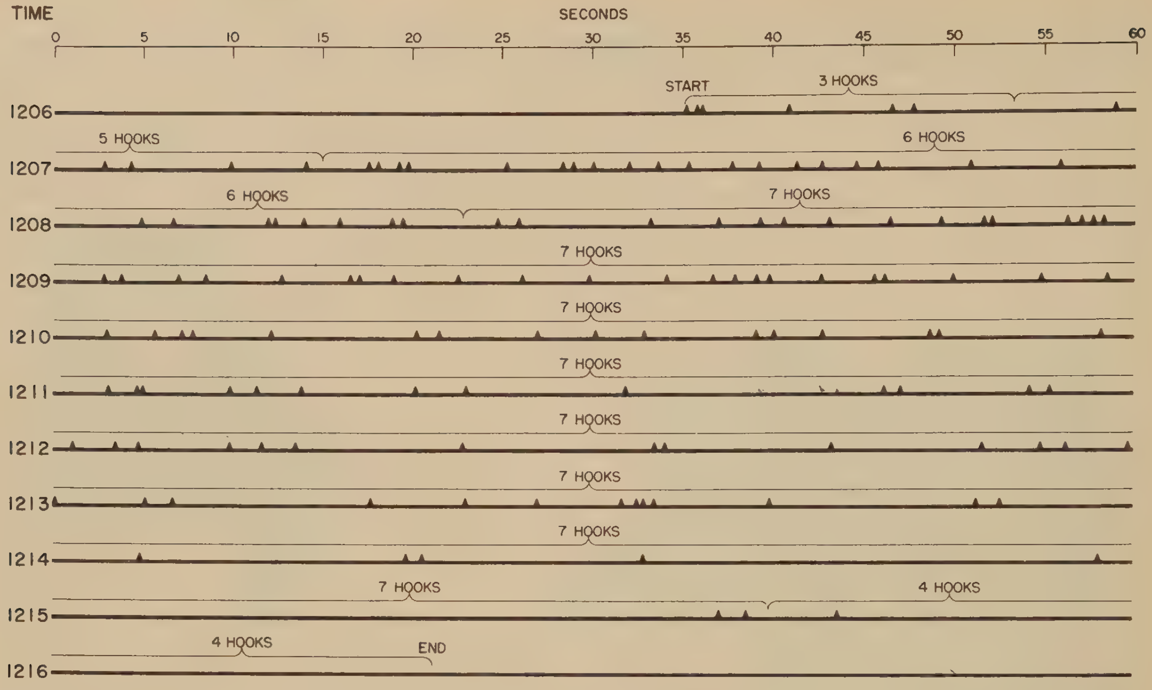


Figure 2.—Plot of the landing of individual skipjack, and time. Each mark represents one skipjack.

displacement to the nearest 0.1 ml. or with an error of about 1 percent depending on the volume. In addition, all fish were ranked by relative stage of digestion.

The fork lengths of the smallest and largest fish in each family from each sample of stomachs were measured. This disclosed the size range of each fish family consumed by an individual skipjack school. The lengths of the squid mantles were likewise measured. Linear measurements of other items were not attempted.

Digested remains were identified whenever possible as fish, mollusks, or crustacean. Otherwise they were classified as "gurry." Volumetric measurements were taken as described earlier.

The bait found in stomachs received the same treatment as other fish, but the results were discarded as unreliable because skipjack often regurgitate much of the bait as they are caught or soon after. At times food deeper in the stomach is also regurgitated but the amount seems negligible.

Trematodes, nematodes, and Acanthocephala were found in the stomachs in small quantities. These were assumed to be parasites and were not considered.

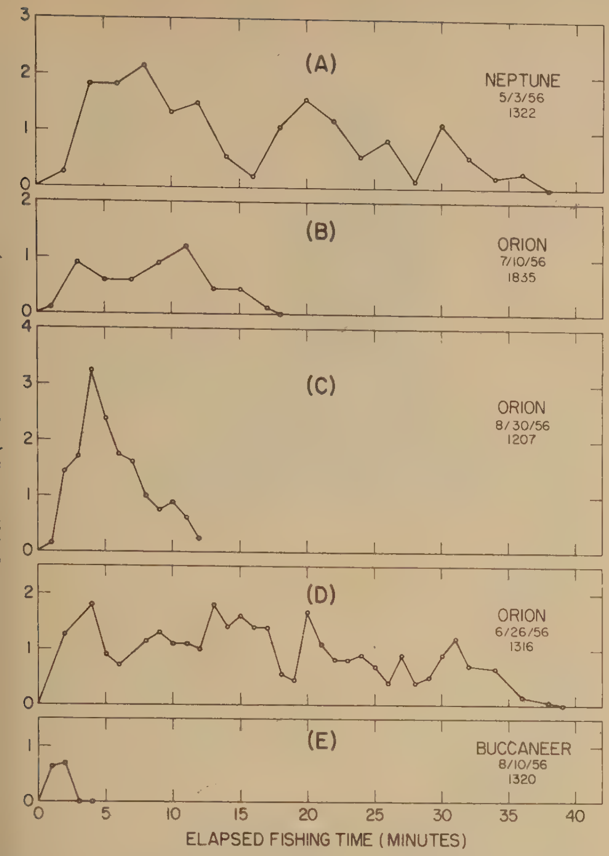
RESULTS

GENERAL INFORMATION ON FISHING

No fish were caught from 52 percent of the schools chummed.

The rate at which the skipjack took the hooks varied. More often than not the fish seemed to bite in short flurries (fig. 2). This may be due to the distributional makeup of skipjack schools. In the few times when the fish could be clearly seen in the water, the schools seemed to be aggregates of many small groups of about 10 fish each.

When the catch rates are plotted against elapsed fishing time at 1- or 2-minute intervals (fig. 3), they present an assortment of shapes. In general there is a rise to a peak with a subsequent decline. Figure 3, *A* shows a relatively early peak, with irregular rise and decline and is typical of most of the plots. Occasionally there are variations as seen in figure 3: *B* illustrates a later peak; *C* has a sharper decline; and *D*, the major peak, is not particularly dominant. *E* is an example of a school that responded poorly. An average of 32.7 percent of the total catch was made during the prepeak period.



IGURE 3.—Plots of catch rates against elapsed fishing time. *A*, typical. *B*, late peak. *C*, sharp decline. *D*, no dominant peak. *E*, poor response.

MEASURES OF BITING RESPONSE

Total catch per school is probably the most conenient measure of a school's response to chum. This would be the measure of most interest if it vere to be applied toward estimating the fishing otential of a new area. Of the schools oberved, the catch per school ranged from 1 to 773. The frequency distributions of catch per school fig. 4) were not normal. Since the lengths of he fish fell into two distinct groups (fig. 5), the istributions were plotted separately.[2]

However convenient a measure the total catch nay be, it is difficult to translate into terms of fish ehavior because it is a reflection of a sum of beavioral and non-behavioral factors. We sought measure of biting response that would be indicaive of both behavior and yield. Correlation procedures as described by Snedecor (1946) were applied to the data to determine which of the measures of the fishing operation were associated with total catch. Since most of the frequency distributions of the various measures were skewed and sometimes truncated, Spearman's method of rank correlation was used. Computing a series of correlation coefficients is not condoned because the probability of encountering a significant correlation due to chance is increased. In this and a later section, however, such computations were included in preliminary surveys to gain information on which to base hypotheses and were not used as grounds for acceptance or rejection.

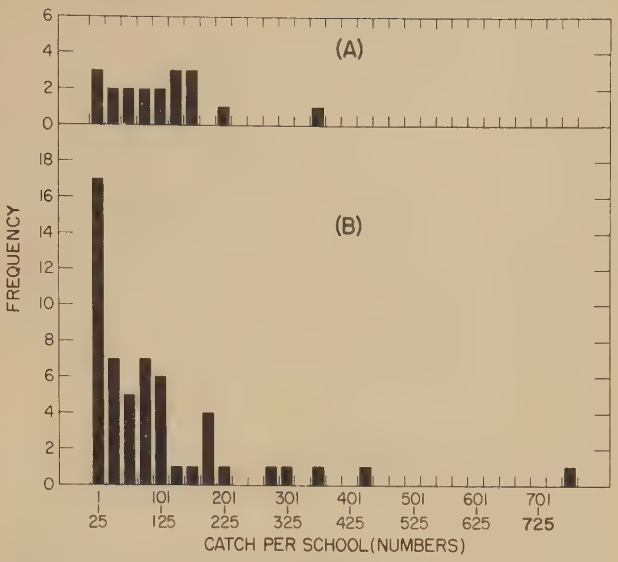


FIGURE 4.—Frequency distributions of catch per school. *A*, represents skipjack smaller than 60 cm. fork length. *B*, represents skipjack greater than 60 cm. fork length.

Fishing duration, which is defined as the time from the introduction of hooks into the water to their final withdrawal, was found to be highly correlated with total catch.[3] The rank correlation coefficient ($r_s=0.710^{**}$) with 84 degrees of freedom is well beyond the 1-percent level of significance. (In accordance with common practice, 2 asterisks (**) will be used to mark values beyond the 1-percent level of significance and one asterisk (*) to mark values beyond the 5-percent level.) Fishing duration ranged from 1 to 82 minutes. The frequency distributions of fishing

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[2] Hereafter the fish will be designated as large or small dependng on whether the sample means of fork lengths were more or ess than 60 cm., respectively.

[3] Data for this and other procedures are tabulated in the appendix, table 5.

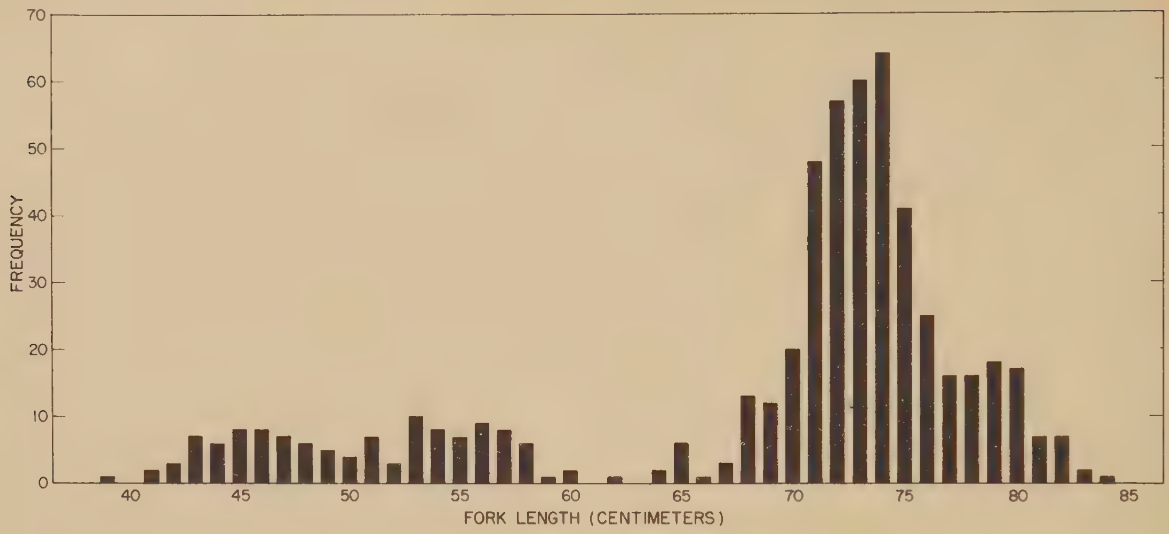


Figure 5.—Frequency distribution of fork lengths of skipjack sampled.

duration of small and large fish (fig. 6) does not depict any obvious difference between the two.

The peak catch rate expressed in terms of fish per hook-minute was also found to be significantly correlated with total catch ($r_s=0.796^{**}$). The range of this variate for both large and small fish is about the same. The frequency distributions of peak catch rates of large and small fish (fig. 7), however, show quite divergent modes. A dominant mode for the large fish lies somewhere between 0.40 and 1.00 fish per hook-minute, while for the small fish the mode seems to be between 3.20 and 3.40 fish per hook-minute. This difference in peak catch rates cannot be attributed entirely to behavioral differences of the two sizes. An undetermined part of the difference is due to the greater ease with which the fishermen land the smaller fish.

The elapsed time from the start of fishing to the peak catch rate (hereafter called prepeak duration) and the time interval from the peak catch rate to the end of fishing or postpeak duration, were also compared with total catch. Postpeak duration and total catch were found to be highly correlated ($r_s=0.750^{**}$), while the prepeak duration and total catch were not ($r_s=0.204$). Prepeak duration ranged from 0.5 to 42.5 min-

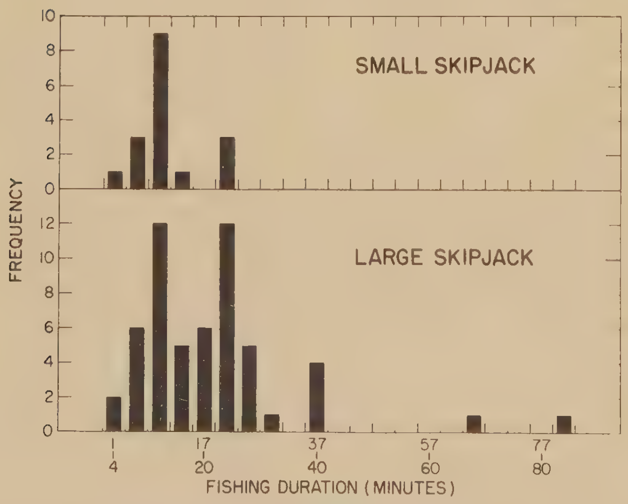


Figure 6.—Frequency distributions of fishing duration of large and small skipjack.

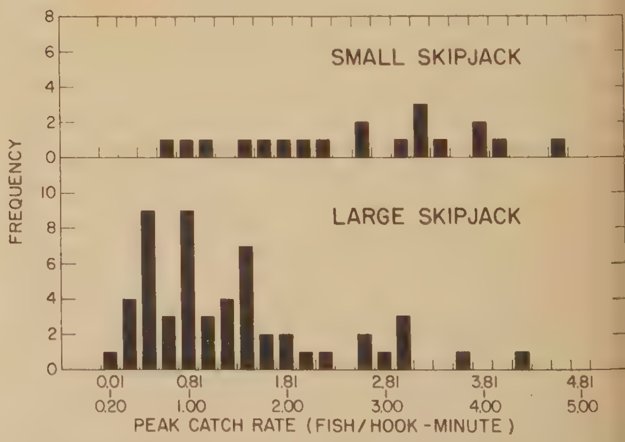
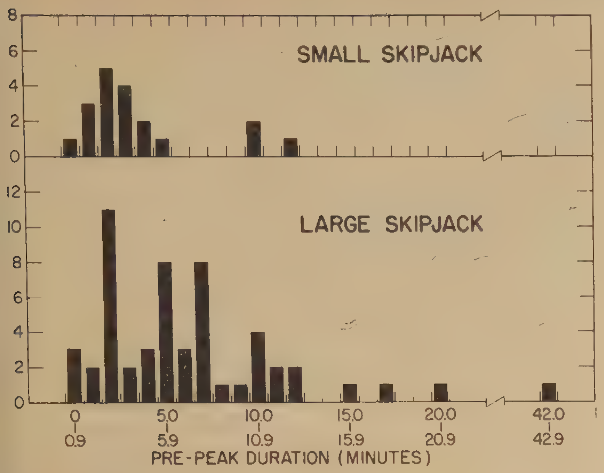


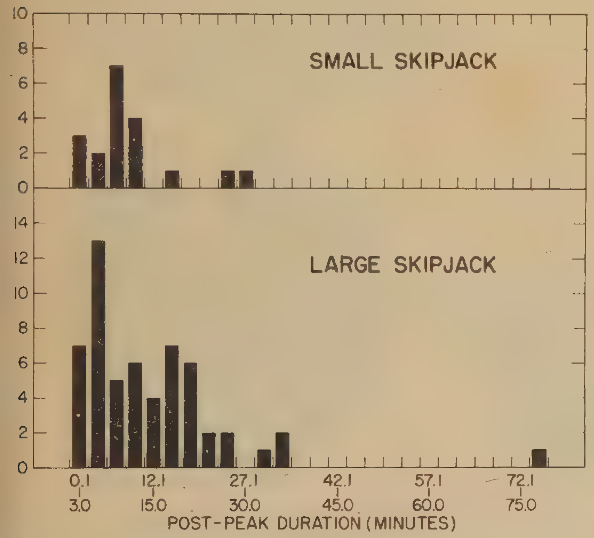
Figure 7.—Frequency distributions of peak catch rates for large and small skipjack.



IGURE 8.—Frequency distributions of prepeak duration for large and small skipjack.

tes (fig. 8) and postpeak duration ranged from to 77 minutes (fig. 9).

The average increase per minute of the prepeak atch rates and the average decrease per minute f the postpeak catch rates for each school were omputed by using regression methods with the ssumption that the rates of increase and decrease ere linear. The frequency distributions of these ates, placed into categories of large and small sh (fig. 10), show greater skewness in the disributions for the large fish. Total catch was ound to be significantly correlated with the rate of prepeak increase ($r_s=0.395^{**}$) but not with the rate of postpeak decline ($r_s=-0.009$).



IGURE 9.—Frequency distributions of postpeak duration for large and small skipjack.

Another factor that affected the total catch was the mean number of hooks fished per minute. The rank correlation coefficient was 0.259*. The grand mean number of hooks fished was 7.38±1.42.

Total catch did not seem to be influenced by the number of passes needed to stop a school (range 1 to 12 passes) nor the time interval from the start of the successful pass to the start of fishing (range of 0 to 31 minutes). The r_s values were -0.043 and 0.111, respectively.

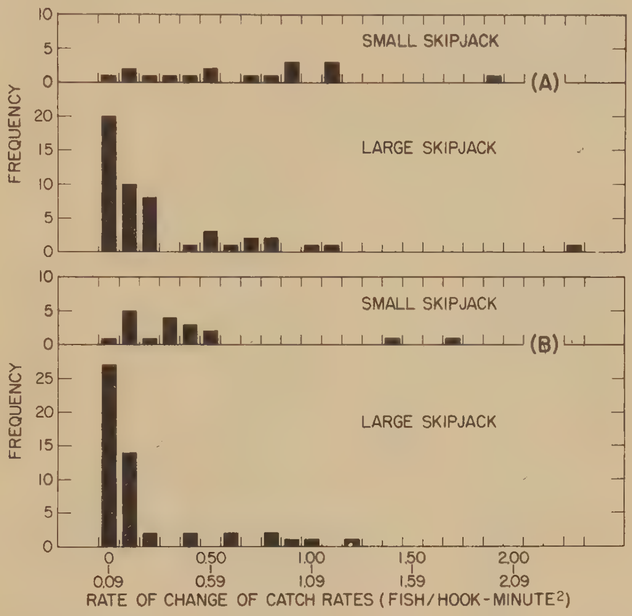


FIGURE 10.—*A*, Frequency distributions of rate of increase of peak catch rates. *B*, Frequency distributions of rate of decrease of postpeak catch rates.

Summarizing (table 1), the measured factors which seemed to influence the catch were (1) postpeak duration, (2) fishing duration, (3) peak catch rate, (4) mean number of hooks per minute, and (5) rate of increase of prepeak catch rates. Of these the peak catch rate and the postpeak duration were chosen as measures of skipjack response for use in later analyses. These, we thought, would be measures of two different aspects of response to chum. The peak catch rate would measure the degree of interest or intensity of the skipjack in feeding, and the postpeak duration would measure the duration of interest.

This by no means implies that these aspects are separate entities. In fact, the rank correlation coefficient between the two is 0.382** which may be interpreted to mean that factors common to both exist, or that one is influenced by the other.

Another consideration is that these measures may also be associated with school size. It is conceivable that a larger school would result in a longer postpeak duration. Perhaps the fish in a larger school would be more densely distributed which would result in a higher peak catch purely on a mechanical basis. It is also possible that behavior is influenced by school size. Unfortunately these possibilities must remain as conjectures for the present as no means for measuring the school size was available.

TABLE 1.—*Correlation coefficients of total catch with various measures of fishing*

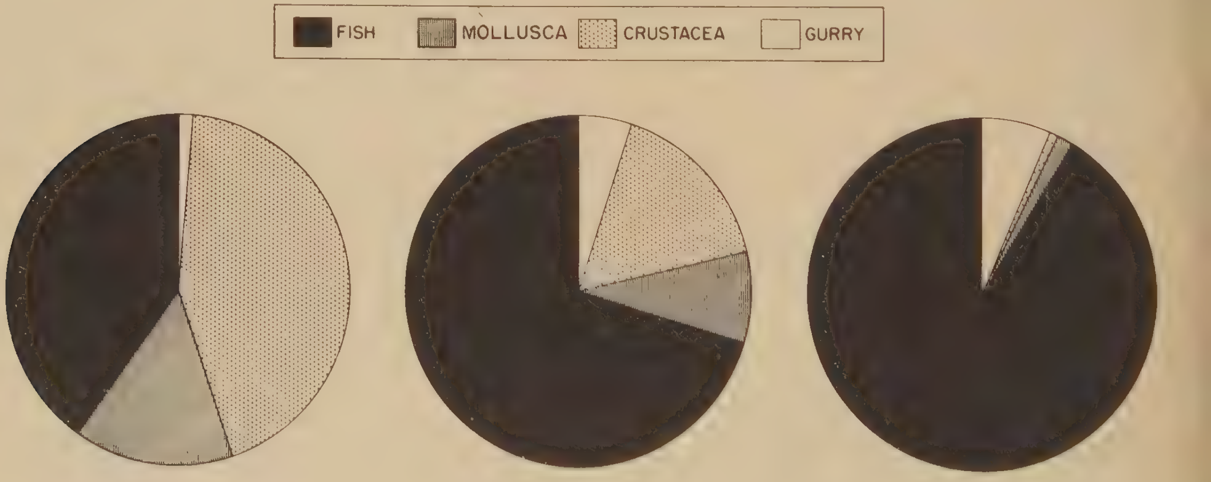
Measure	Degrees of freedom	r
Fishing duration	84	0.772**
Peak catch rate	84	.614**
Prepeak duration	84	.201
Postpeak duration	84	.868**
Rate of prepeak increase	71	.274*
Rate of postpeak decrease	73	−.120
Mean number of hooks	84	.289**
Number of passes	81	−.06
Time from start of pass to start of fishing	79	.01

DESCRIPTION OF STOMACH CONTENTS

For descriptive purposes, the group designated as small fish was further divided into two groups with 50 cm. as the separating point. The volume of the stomach contents varied markedly with fish size. The mean volume for large fish was 35.6 ml./fish. The school means ranged from 2.4 to 154.1 ml./fish. Skipjack 50 to 60 cm. in fork length showed a mean volume of 20.4 ml./fish with school means ranging from 1.5 to 55.6 ml./fish while skipjack shorter than 50 cm. had a mean volume of 9.1 ml./fish with school means ranging from 1.3 to 15.2 ml./fish.

The food of the skipjack of the different size groups was alike and consisted of fish, mollusks and crustaceans, but in different proportions During the fishing season, fish accounted for 91 percent by volume of the large skipjack's diet but contributed less to the food of the smaller skipjack (fig. 11). The percentage compositions of fish in the stomachs of skipjack of 50 to 60 cm. long and skipjack less than 50 cm. long were 70 percent and 40 percent, respectively. On the other hand, mollusks and crustaceans were of relatively increasing importance with a decrease in size.

The six schools sampled during the off season October 1956 through March 1957, produced somewhat different percentage compositions (fig. 12) Three of the schools were composed of skipjack estimated at 12 to 13 pounds and the other three consisted of skipjack estimated at 22 pounds. All of these fish would be classified as large. The percentage of fish in the stomachs was 59 percent as compared to 91 percent found during the season

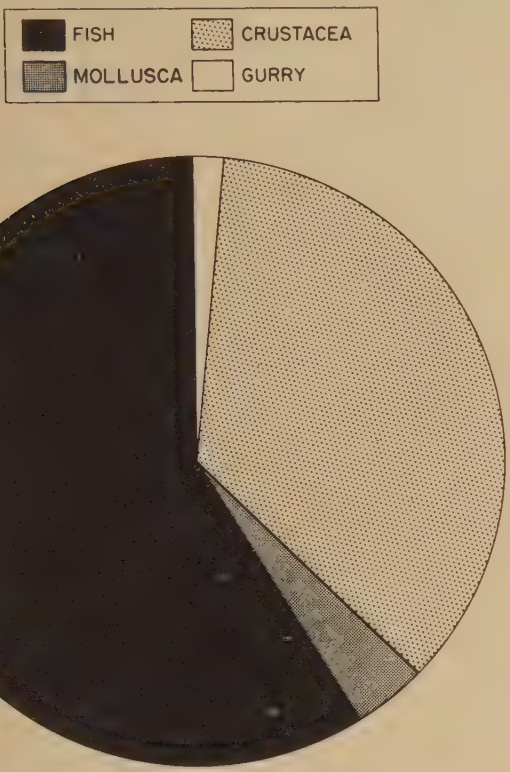


FORK LENGTH < 50 CM. FORK LENGTH 50-60 CM. FORK LENGTH > 60 CM.

FIGURE 11.—Diagrams illustrating the composition by volume of the stomach contents of three sizes of skipjack caught during the fishing season.

ther difference between the diets of season and season skipjack was the percentage of crusta- s. The figures are 36 percent for nonseason jack and less than 1 percent for season skip- .

epresentatives of 30 fish families and a few lentified fish were found in the stomach con- s. The families are listed in table 2 in order ercentage of total mean volume. The percent- s listed are for fishes of the season and were ulated in the following manner to compensate the difference in sample sizes. First, the mean ume of each category in units of ml./stomach s taken for each school. Then the total mean lume of each category was divided by the grand al mean volume and converted to percentages. this way the contents from each school were ven equal weight regardless of sample size. rangids (genus *Decapterus*) were by far the st important item in terms of both volume and currence. The genus *Cubiceps* of the family meidae also contributed considerably to the volumes. Gurry, a small piece of wood, and a cigarette butt were classed under miscellaneous.



URE 12.—Diagram illustrating the composition by volme of stomach contents of large skipjack caught durng the off season.

FACTORS INFLUENCING BITING RESPONSE

As selected in a previous section, peak catch rate and postpeak duration were used as measures of biting response. These were compared with a number of possible factors by correlation procedures or by plotting.

TABLE 2.—*Stomach contents of skipjack from 34 schools*

Contents		Percentage of total mean volume	Occurrence (number of schools)
Fish	Carangidae	45.01	27
	Nomeidae	20.25	10
	Molidae	6.45	6
	Thunnidae	3.14	13
	Gempylidae	2.27	19
	Sudidae	1.53	1
	Holocentridae	1.04	11
	Chaetodontidae	.92	21
	Bramidae	.59	10
	Scorpaenidae	.28	15
	Mullidae	.13	4
	Acanthuridae	.11	9
	Balistidae	.11	7
	Sphyraenidae	.10	1
	Exocoetidae	.07	2
	Serranidae	.06	1
	Diodontidae	.05	1
	Synodontidae	.04	4
	Priacanthidae	.03	2
	Blenniidae	.02	3
	Ammodytidae	.02	3
	Fistularidae	.01	2
	Antigonidae	.01	1
	Cirrhitidae	.01	2
	Dactylopteridae	.01	2
	Ostraciidae	.01	4
	Syngnathidae	Trace	1
	Pomacentridae	Trace	1
	Tetrodontidae	Trace	1
	Pegasidae	Trace	1
	Unidentified fish	.42	20
Mollusks	Decapoda	2.28	24
	Octopoda	.02	1
Crustacea	Stomatopoda	2.51	24
	Decapoda	.94	23
	Amphipoda	.08	7
	Isopoda	Trace	5
	Euphausiacea	Trace	1
Miscellaneous		11.49	34

SKIPJACK SIZE

The mean length of the skipjack for each school was found to be significantly correlated with peak catch rate ($r_s = -0.475^{**}$). As mentioned earlier, this is at least in part attributed to the greater facility with which the small fish were landed. Correlation between mean length and postpeak duration ($r_s = -0.058$) was not significant.

HUNGER AND TIME SINCE LAST MAJOR FEEDING

The mean volume of the stomach contents (ml./stomach) for each school was used as a measure of the state of hunger. The time since the last major feeding was expressed by the lowest stage of digestion found in the dominant fish family or families in the stomach contents of a school, using the following criteria:

Stage 1. Fish intact.
Stage 2. Skin or head missing.
Stage 3. Part of flesh missing
Stage 4. Skeletal remains.

Since the rate of digestion is not known, this measure is a relative one. Only the large skipjack caught during the season provided sufficient data for this study.

Since the stage of digestion was found to be highly correlated with the mean volume ($r_s = -0.607^{**}$), partial correlation procedures (Snedecor 1946) were used to assess the relations of these variates to biting response. Although the variates did not meet the assumption of normality, we found no other satisfactory technique and thought that these relations should be investigated.

The peak catch rate was not significantly correlated with either variate. This is in contrast to the findings of Uda (1933) and Suyehiro (1938). The former stated that skipjack with stomachs between the extremes of fullness and emptiness tended to respond more poorly to fishing when their stomachs were emptier. The latter observed that skipjack which had fed recently did not bite so well as those that were hungry. His measure of the recentness of feeding was the depth of the rugae; i.e., a smooth stomach lining indicated recent feeding. We suspect, however, that the depth of the rugae is directly related to the state of distention of the stomach, which depends upon the amount of food in it.

Multiple correlation computations of postpeak duration with stage of digestion and mean volume resulted in $R = -0.565^{*}$. In further computations, the partial correlation coefficient between postpeak duration and stage of digestion, independent of mean volume, was found to be -0.535^{*} and that between postpeak duration and mean volume, independent of stage of digestion, was found to be -0.506^{*}. That is to say, the postpeak duration was longer when the major items in the stomachs were in the earlier stages of digestion and the stomachs were emptier.

From this we hypothesize that live-bait fishing techniques employed in Hawaii generally do not create a state of feeding excitement in the ski jack, but exploit an already existing one whi apparently is caused by the presence of natur food. The fact that less than one-half of t schools respond to chum supports the hypothes Furthermore, the correlations infer that the sta of excitement diminishes with feeding or wi time if the skipjack were not satiated when t natural food became unavailable.

PREY BEHAVIOR

In order to determine whether any associati existed between prey behavior and biting behavi of skipjack, schools were grouped according families of fish in their stomachs. Only first a second stages of digestion were considered, an if a school of fish had representatives of sever families, the school was tabulated in each fami classification. The mean peak catch rate a mean postpeak duration for each group repr sented by four or more schools were computed. A an example, the mean peak catch rate and t mean postpeak duration were calculated for schools with the family Carangidae in the fi and second stages of digestion.

The families are listed in tables 3 and 4 in d scending order of their means. If the famili were classified by their swimming abilities, t

TABLE 3.—*List of fish families and peak catch rate mea*

Family	Mean p catch ra (fish/ho minut
Nomeidae	
Thunnidae	
Carangidae	
Gempylidae	
Chaetodontidae	
Scorpaenidae	
Molidae	
Acanthuridae	

TABLE 4.—*List of fish families and postpeak durat means*

Family	Postpe durati (minut
Nomeidae	
Thunnidae	
Gempylidae	
Scorpaenidae	
Acanthuridae	
Carangidae	
Molidae	
Chaetodontidae	

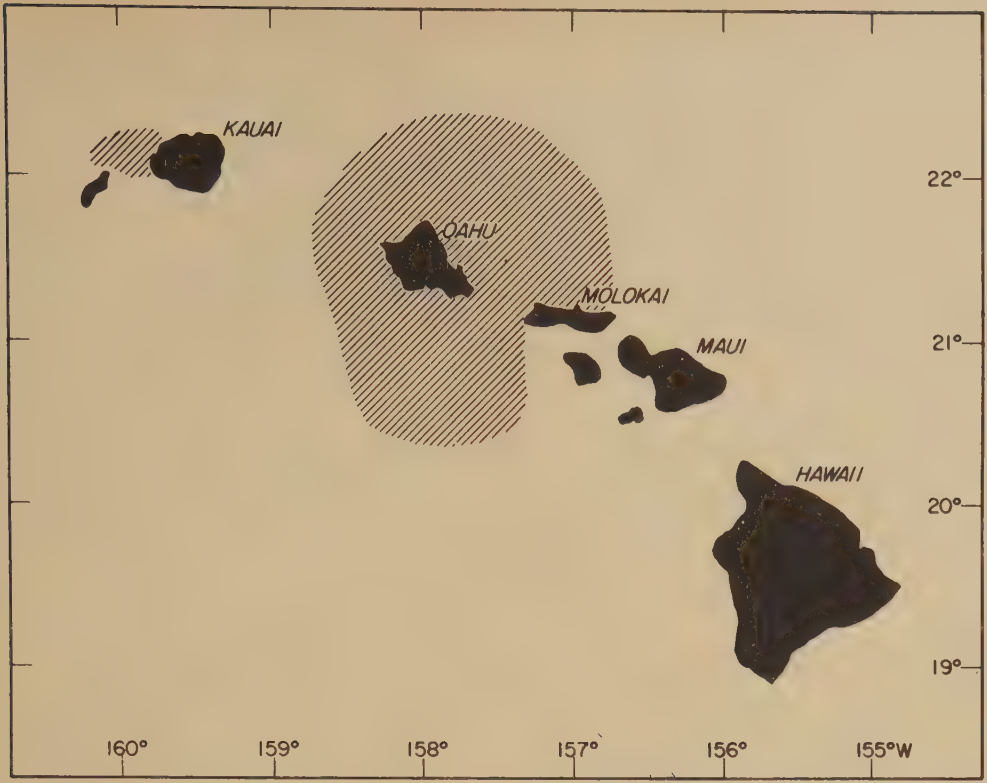


FIGURE 13.—Chart showing the areas of fishing where observations were made.

t swimmers would include the families Thun- lae, Carangidae, Gempylidae, and Nomeidae, ile the remainder would be considered slow immers. The fast swimmers are in the top ir positions of table 3 and in the top three posi- ns of table 4. It therefore appears that skip- k feeding on fast-swimming fish exhibit a more vorable biting behavior than skipjack feeding slow-swimming fish.

STATE OF OVARY DEVELOPMENT

The ovaries collected from the large skipjack re all maturing. A few of the eggs were teased om the group of largest eggs in each ovary, and diameters of five were measured. The great- diameter found in each school was used as a ugh measure of maturity. The correlations of g diameters with peak catch rate (r_s=0.086) d postpeak duration (r_s=0.258) were not sig- icant. The absence of ripe skipjack in the ch may be due to the reluctance of such skip- k to feed, but the stages of egg maturation er than ripeness do not appear to affect biting ponse.

LOCATION

All observations were made in the regions represented by the shaded areas in figure 13. The shaded area at the west end of the island of Kauai represents only one trip. The rest of the trips were within the shaded area around the island of Oahu.

The peak catch rate for large fish showed a positive significant correlation with distance from land (r_s=0.308*). For small fish, the correlation was not significant (r_s=0.057). No significant correlation was found between postpeak duration and distance from land for either large or small fish (r_s values of -0.040 and -0.224, respectively).

TIME OF DAY

Examination of peak catch rate, postpeak duration, and the percentage of schools successfully fished relative to time of day indicated no relation. Data on the Japanese skipjack fishery (Uda 1940a) show that catches were highest between 6 a.m. and 8 a.m., but the peak was not reflected in the catch rates. Suyehiro (1938) stated that fishing was best during early morning but provided no data.

WEATHER CONDITIONS

The weather conditions were predominantly uniform and biting behavior did not change on the unusual days. The height of the sea ranged from 1 to 10 feet, with 2 to 5 feet being the usual condition. Estimations of wind velocity ranged from 0 to 30 knots, but most of the estimates were between 10 and 20 knots. Most of the days were bright and sunny. The few darker days affected fishing only in decreasing the chances of sighting schools.

SUMMARY AND CONCLUSIONS

Commercial fishing of 92 skipjack schools was observed and resulted in the following information:

1. Fifty-two percent of the schools chummed yielded no fish.
2. The number of fish caught per school varied from 1 to 773.
3. Total fishing time per school varied from 1 to 82 minutes.
4. The number of passes required to stop a school varied from 1 to 12.
5. The mean number of hooks fished per school was 7.38 ± 1.42.
6. Although the catch rate varied during fishing operations, the general tendency was to rise to a peak and then decline with elapsed fishing time.
7. The peak catch rate ranged from 0.12 to 4.29 fish per hook-minute for large skipjack (fork length greater than 60 cm.) with a mode of 0.40 to 1.00 fish per hook-minute, while small skipjack (fork length less than 60 cm.) had a range of 0.75 to 4.62 fish per hook-minute with a mode of 3.20 to 3.40 fish per hook-minute.
8. The prepeak duration ranged from 0.5 to 42.5 minutes with a mode of 2 to 3 minutes.
9. The postpeak duration ranged from 0 to 77 minutes with a mode of 3 to 6 minutes.
10. The catch per school was affected by fishing duration, postpeak duration (which is part of fishing duration), peak catch rate, number of hooks fishing, and the rate of increase of prepeak catches.

Examination of the contents of 573 stomachs representing 49 schools revealed the following:

1. The mean volumes of stomach contents fo skipjack of fork length greater than 60 cm., 50 t 60 cm., and less than 50 cm. were 35.6 ml., 20.4 ml and 9.1 ml., respectively.
2. The percentage of fish in the stomachs co lected during the fishing season decreased with decrease in skipjack size while the percentages c mollusks and crustaceans increased.
3. The percentage of fish in the stomachs c large skipjack caught during the off season wa less than that of those caught during the seasor The reverse was true of the percentage of cru taceans.
4. The fish contributing most to the diet c skipjack were the genus *Decapterus*, of the famil Carangidae, and the genus *Cubiceps*, of the fan ily Nomeidae.
5. Representatives of more than 30 families c fish were found in the stomachs.

A study of the causal factors of the variatic in biting response showed that—

1. Large skipjack tended to take the hool faster the farther away they were from land.
2. The duration of response to chum was neg tively correlated with mean stomach volumes ar the stage of digestion of the dominant compone of the stomach contents.
3. Skipjack feeding on fast-swimming fish we caught at a faster rate and fished for a long period than those feeding on slow-swimming fis
4. The relation between the state of ovary d velopment and biting response is not clear, b only skipjack in the maturing stage were caugl In the maturing stage there was no correlation b tween biting response and a slight gradient in eg development.
5. Biting response was not affected by the tir of day or weather conditions.

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APPENDIX

Data from schools fished during skipjack season

[Data from 6 schools fished in competition with other boats are not listed]

Date	Starting time	Total catch	Number of passes needed to stop school	Prepeak duration (minutes)	Postpeak duration (minutes)	Fishing duration (minutes)	Mean number of hooks fished (hooks/minute)	Peak catch rate (fish/hook-minute)	Rate of increase of prepeak catch rates (fish/hook-minute)	Rate of decrease of postpeak catch rates (fish/hook-minute)	Distance from land (miles) [1]	Fish size [2]	Mean volume of stomach contents (ml./stomach)	Lowest stage of digestion of major components
1956														
ay 3	1036	5	2	10.5	0.5	11	6.5	0.50	0.02	----------	----------	B	----------	----------
3	1322	280	1	7.0	31.0	38	7.9	2.17	.28	0.045	----------	B	----------	----------
8	1453	49	1	7.0	7.0	14	7.7	.88	.10	.125	30 W	B	----------	----------
8	1614	11	1	5.0	4.0	9	7.3	.42	.27	.124	----------	B	----------	----------
8	1630	47	1	15.0	6.0	21	6.9	.75	.03	.104	----------	B	----------	----------
8	1805	81	7	3.0	4.0	7	8.3	2.25	.62	.689	----------	B	----------	----------
15	0815	87	1	5.0	12.0	17	8.8	1.15	.18	.061	20 L	B	----------	----------
15	0900	66	3	5.0	16.0	21	8.1	1.06	.21	.068	20 L	B	----------	----------
16	1538	15	1	7.0	17.0	24	7.6	.29	.02	.014	18 L	B	----------	----------
ne 21	0845	197	1	0.5	20.5	21	9.7	3.62	----------	.094	10 W	B	----------	----------
21	1203	47	1	1.0	13.0	14	9.1	0.75	----------	.065	15 W	----------	----------	----------
21	1412	773	1	5.0	77.0	82	9.7	3.18	.78	.031	20 W	B	18.6	1
26	1242	118	1	7.0	17.0	24	10.0	1.45	.16	.050	30 W	B	32.5	2
26	1316	355	1	3.0	36.0	39	9.9	1.80	.28	.032	30 W	B	14.1	3
26	1459	44	1	4.5	5.5	10	9.4	.89	.16	.114	30 W	B	----------	----------
26	1522	245	1	3.5	23.5	27	9.0	1.89	.50	.038	30 W	----------	----------	----------
26	1629	140	1	6.0	15.0	21	6.0	2.50	.42	.139	25 W	----------	----------	----------
29	1112	4	2	5.0	4.0	9	7.3	.12	.03	.034	----------	B	154.1	1
29	1142	104	1	9.0	13.0	22	9.0	1.20	.14	.084	----------	B	----------	----------
29	1613	110	1	7.0	18.0	25	7.8	1.50	.27	.052	----------	B	54.3	2
ly 3	0910	79	2	12.0	12.0	24	7.5	1.00	.03	.041	10 W	B	41.6	2
4	1002	58	1	2.0	21.0	23	6.8	.69	.28	.019	10 W	B	41.6	1
4	1204	66	4	10.0	11.0	21	7.7	1.92	.14	.148	6 W	B	101.8	1
10	0907	54	2	2.0	16.0	18	9.0	1.22	.56	.044	15 W	B	22.6	2
10	0950	79	1	2.0	10.0	12	9.2	1.28	.59	.111	15 W	B	----------	----------
10	1002	32	1	2.0	10.0	12	8.2	.50	.18	.070	15 W	B	----------	----------
10	1116	106	3	7.0	16.0	23	8.9	1.50	.11	.089	6 W	B	9.1	2
10	1835	90	5	10.0	8.0	18	8.7	1.21	.08	.153	5 W	B	----------	----------
17	0824	4	3	6.0	.0	6	10.3	.22	.04	----------	10 W	B	----------	----------
17	1146	244	2	12.0	27.0	39	8.4	1.56	.09	.040	12 W	B	74.0	2
19	0811	39	1	8.0	5.0	13	6.2	.92	.08	.200	18 L	B	2.4	3
19	1245	140	12	7.0	14.0	21	6.7	1.83	.02	.121	50 L	B	5.7	3
19	1352	94	1	2.0	18.0	20	6.0	1.56	.71	.064	60 L	----------	----------	----------
24	1130	8	1	5.0	4.0	9	7.0	.21	.03	.065	10 L	B	37.3	2
24	1721	120	7	7.0	20.0	27	6.7	1.50	.20	.040	5 L	B	30.0	1
25	0916	6	4	5.0	2.0	7	6.0	.42	.14	.420	20 L	B	----------	----------
25	1602	12	5	5.0	5.0	10	6.0	.50	.09	.125	15 L	B	----------	----------
26	0734	23	1	11.5	5.5	17	7.8	.38	.01	.063	15 L	B	----------	----------
26	0918	43	1	17.5	12.5	30	7.4	.83	.01	.038	10 L	B	----------	----------
26	1248	51	1	20.5	5.5	26	7.0	.60	.01	.153	8 L	B	----------	----------
27	1003	165	1	42.5	22.5	65	6.0	1.40	.00	.041	10 L	B	----------	----------

See footnotes at end of table.

Data from schools fished during skipjack season—Continued

Date	Starting time	Total catch	Number of passes needed to stop school	Prepeak duration (minutes)	Postpeak duration (minutes)	Fishing duration (minutes)	Mean number of hooks fished (hooks/minute)	Peak catch rate (fish/hook-minute)	Rate of increase of prepeak catch rates (fish/hook-minute)	Rate of decrease of postpeak catch rates (fish/hook-minute)	Distance from land (miles) [1]	Fish size [2]	Mean volume of stomach contents (ml./stomach)	Lowest stage of digestion of major components
1956														
Aug. 8	1221	30	4	2.5	9.5	12	5.6	1.67	1.17	0.171	30 L	B	18.6	3
9	0942	10	2	6.5	1.5	8	7.0	0.86	.09	.860	20 L	B	106.2	2
10	0810	35	3	2.5	4.5	7	6.9	1.83	1.16	.466	2 W	S	4.7	-----
10	1134	21	4	1.5	5.5	7	6.4	.92	-----	.103	¾ W	S	1.3	-----
10	1320	12	1	1.5	1.5	3	8.7	.70	-----	-----	50 L	B	-----	-----
22	1025	3	3	.5	1.5	2	7.0	.50	-----	-----	40 L	B	11.0	3
30	1207	123	9	3.5	8.5	12	7.8	3.25	.96	.332	30 L	S	15.1	-----
30	1331	171	3	3.5	8.5	12	7.5	4.00	.99	.294	30 L	S	22.6	-----
30	1407	19	1	2.5	2.5	5	7.2	1.14	.50	.570	30 L	S	20.7	-----
30	1440	139	1	11.5	18.5	30	7.2	1.75	.05	.071	25 L	-----	-----	-----
Sept. 12	0930	113	3	2.0	4.0	6	8.8	3.06	1.03	.630	30 L	B	9.2	3
12	0956	82	2	11.5	8.5	20	6.8	1.57	.03	.115	30 L	B	-----	-----
1957														
May 23	0750	52	2	2.5	.5	3	6.7	3.12	-----	-----	10 W	-----	-----	-----
23	0832	2	1	.5	.5	1	5.0	.40	-----	-----	20 W	-----	-----	-----
23	0846	13	1	1.5	.5	2	5.0	2.20	-----	-----	20 W	-----	-----	-----
23	0912	17	1	1.5	.5	2	6.0	2.14	-----	-----	20 W	-----	-----	-----
23	1301	22	3	2.5	5.5	8	6.9	1.00	.50	.123	20 W	B	4.5	3
23	1612	189	11	1.5	21.5	23	6.9	2.80	2.30	.109	25 W	B	-----	-----
June 13	1207	128	1	2.5	7.0	10	6.4	3.29	.58	.382	20 W	S	15.2	-----
19	1007	19	4	.5	8.5	9	8.6	.88	-----	.041	10 W	B	-----	-----
19	1023	19	1	4.5	8.5	13	7.5	.44	.09	.038	15 W	B	33.7	2
19	1222	23	3	10.5	2.5	13	7.4	1.00	.02	1.000	-----	B	-----	-----
19	1343	94	4	6.5	18.5	25	7.7	1.50	.18	.050	20 W	B	9.4	2
July 3	0950	111	5	10.5	10.5	21	5.6	4.62	.30	.189	3 W	S	3.3	-----
3	1040	358	-----	2.5	25.5	28	7.2	4.00	1.12	.156	20 L	S	11.0	-----
3	1207	142	-----	2.5	9.5	12	7.2	3.50	.95	.445	20 L	S	-----	-----
3	1228	67	1	3.5	6.5	10	6.9	2.71	.81	.385	25 L	S	-----	-----
3	1317	71	1	3.5	9.5	13	7.2	1.57	.15	.113	30 L	S	-----	-----
3	1353	207	1	12.5	8.5	21	7.3	3.38	.02	.405	30 L	S	-----	-----
3	1430	83	1	4.5	6.5	11	7.7	1.62	.25	.296	30 L	S	-----	-----
3	1510	95	1	10.5	1.5	12	6.8	2.71	.11	1.700	30 L	S	-----	-----
3	1528	6	1	.5	1.5	2	5.0	.75	-----	-----	30 L	S	-----	-----
3	1552	41	-----	1.5	10.5	12	6.6	2.12	1.12	.140	30 L	S	-----	-----
Aug. 1	1543	188	1	2.5	16.5	19	6.9	3.00	.72	.196	40 W	B	7.3	-----
1	1610	431	1	2.5	35.5	38	6.7	4.29	.86	.090	40 W	B	-----	-----
1	1747	2	2	.5	1.5	2	7.0	.29	-----	-----	40 W	-----	-----	-----
1	1753	337	1	10.5	14.5	25	6.9	3.57	.21	.233	40 W	-----	-----	-----
6	0626	157	1	4.5	27.5	32	7.9	2.33	.47	.031	1½ L	S	31.8	-----
14	0941	84	1	2.5	16.5	19	5.8	3.00	1.50	.103	30 L	-----	-----	-----
14	1007	15	2	2.5	12.5	15	6.5	.43	.22	.004	20 L	B	23.5	2
14	1806	158	1	5.5	15.5	21	6.9	3.14	.71	.172	10 L	S	55.6	-----
21	1353	133	2	1.5	7.5	9	7.6	4.14	1.94	.579	55 L	S	1.5	-----
21	1603	178	1	4.5	5.5	10	7.5	3.12	.44	.403	40 L	B	214.1	1
21	1706	13	4	2.5	0.5	3	5.0	1.40	-----	-----	40 L	-----	-----	-----
21	1734	315	1	2.5	25.5	28	7.7	2.71	.86	.069	40 L	B	-----	-----

[1] W=Windward. L=Leeward.

[2] B=mean length > 60 cm. S=mean length <60 cm.